VOL. 33, NO. 2. APRIL, 1956

TROPICAL AGRICULTURE

THE JOURNAL OF THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

CONTENTS

		Page
Editorial	.. ..	85
J. G. Ossewaarde	*C.G.O.T. Ground-nut Scheme in French West Africa* ..	86
H. W. Herbert	*Queensland — A Tropical Curiosity*	95
W. H. Beckett and S. L. Anyane	*Agricultural Surveys with Particular Reference to Tropical Forest Conditions*	101
G. E. Tidbury	*Response of Rice to Certain Fertilizers in Zanzibar*	113
H. Broeshart	*The Application of Foliar Analysis to Oil Palm Cultivation: I. Sampling Technique*	127
K. F. Salmond	*Insect Infestation in Stored Rice in Nyasaland*	134
G. W. Ivens and D. G. Cochrane	*Effects of 2,4,5-Trichlorophenoxyacetic Acid on Evergreen Thicket Vegetation in Kenya*	136
R. H. Williams	Salvinia Auriculata *Aubl.: the Chemical Eradication of a Serious Aquatic Weed in Ceylon*	145
W. C. Kennard	*Effect of Defoliation on Two Clones of* Derris elliptica ..	158
Book Reviews	.. ..	162
Recent Publications	.. ..	169

PRICE : 10s. net post free

(£2 per annum for four quarterly numbers)

Published

on behalf of the College by

BUTTERWORTHS SCIENTIFIC PUBLICATIONS

88 Kingsway, London, W.C.2

COMMONWEALTH MYCOLOGICAL INSTITUTE
19 APR 1956

The case of *Odontotermes obesus* . . .

In Pakistan, groundnuts have considerable potential value as a cash crop — provided that they can be protected from the attacks of the termite *O. obesus*.

Termites are subterranean pests which normally feed on dead plant tissues but, once they have invaded cultivated ground where vegetable debris from previous crops is always plentiful, they soon augment their diet from the growing crop. Groundnuts, because the tips of the shoots enter the soil to bury the seed are particularly liable to attack.

In 1954, following the destruction of 200 acres of groundnuts on a single farm, the Shell insecticide aldrin was used for termite control. The result was a bumper harvest with yields up ten times in the irrigated areas and up six times without irrigation. Germination was 99% throughout, against 20-30% in the untreated plot which was retained for check purposes.

Since this demonstration of its effectiveness as a soil insecticide, aldrin has come into general use and, at 1 lb. per acre, is giving complete protection from termites to Pakistan's valuable groundnut production.

Aldrin, dieldrin, endrin . . . these three advanced insecticides developed by Shell are complementary to each other. Between them they control most of the major insect pests which menace agricultural production and public health throughout the world. Have you an urgent pest problem in your area?

aldrin

aldrin, dieldrin and endrin are SHELL insecticides for world-wide use

For further information apply to your Shell Company · Issued by The Shell Petroleum Company Ltd, London E.C.3. England

Editorial

Imperial College of Tropical Agriculture Reunion
London 1956

It is anticipated that the Imperial College of Tropical Agriculture Annual Reunion will be held again in London this year on Friday, 20th July, at 4 Whitehall Court, S.W.1. It will probably take the form of a cocktail party, as this type of gathering proved popular in 1955. Details will be available from: J. E. Mayne, National Institute of Agricultural Engineering, Silsoe, Bedfordshire, England.

The C.G.O.T. Ground-nut Scheme in French West Africa

J. G. Ossewaarde

Secretary, Netherlands Advisory Board for the Mechanization of Agriculture in the Overseas Territories

The *Plan de Modernisation et d'Équipement* issued by the French Government directly after the 1939–45 war, in order to bring France's economic equipment at home and in the oversea territories up to standard again, provided—among other matters in agriculture—for the foundation of a *Companie Générale des Oléagineux Tropicaux*, (C.G.O.T.), with the task of developing the production of fats and oils within the French Union. As in the British ground-nut scheme in Tanganyika, hopes were fixed on the mechanical cultivation of the ground-nut, and districts in Casamance (Senegal), French Sudan, Haute Volta, North Cameroons and the French Middle Congo seemed to offer good possibilities.

Areas in Casamance were the first to be developed, and some interesting points from experiences and results there since 1950 are described in this article.

The project area, on the Casamance river, is in a district with a population density of 1 to 5 inhabitants per sq. km, so no difficulties have arisen because of dispossession of the inhabitants.

The original plan visualized the development of 200,000 ha. of waste land, one part as a fully mechanized plan under direct control of the C.G.O.T. *culture en régie*, the other as a partly mechanized settlement project in co-operation with the natives, *culture en association*.

At the time of our visit the fully mechanized concern consisted of the first *unité de culture* (UC1), an area of 1700 ha., while the *culture en association* embraced an area of 340 ha. with a *paysannat* of 78 families.

The central depot, Séfa, with administration buildings, workshops, warehouses, *etc*, lies at a point that can be reached by river craft of shallow draught. Séfa is connected by road with Ziguinchor, where the river Casamance is navigable by sea-going vessels.

The area is flat to slightly sloping, and the soils are mainly light with almost identical profiles. There are two types, distinguished by colour as red and beige soils. The clay fractions range from 8 to 15 per cent. The soils are poor in phosphates, with humus content between 0·6 and 2 per cent and the *p*H 6·2 to 6·8.

In moist conditions, the soils are easy to work, but when dry form a concrete-like mass that no normal implement can penetrate. Tools are subject to very rapid wear because of the high quartz content.

There is a single rainy period with an annual rainfall of 1200 to 1500 mm, with an average distribution as shown in *Figure 1*. The average monthly temperatures for 1950–53 ranged from 22°C to 31·4°C and the relative humidity from 14·2 to 99·0.

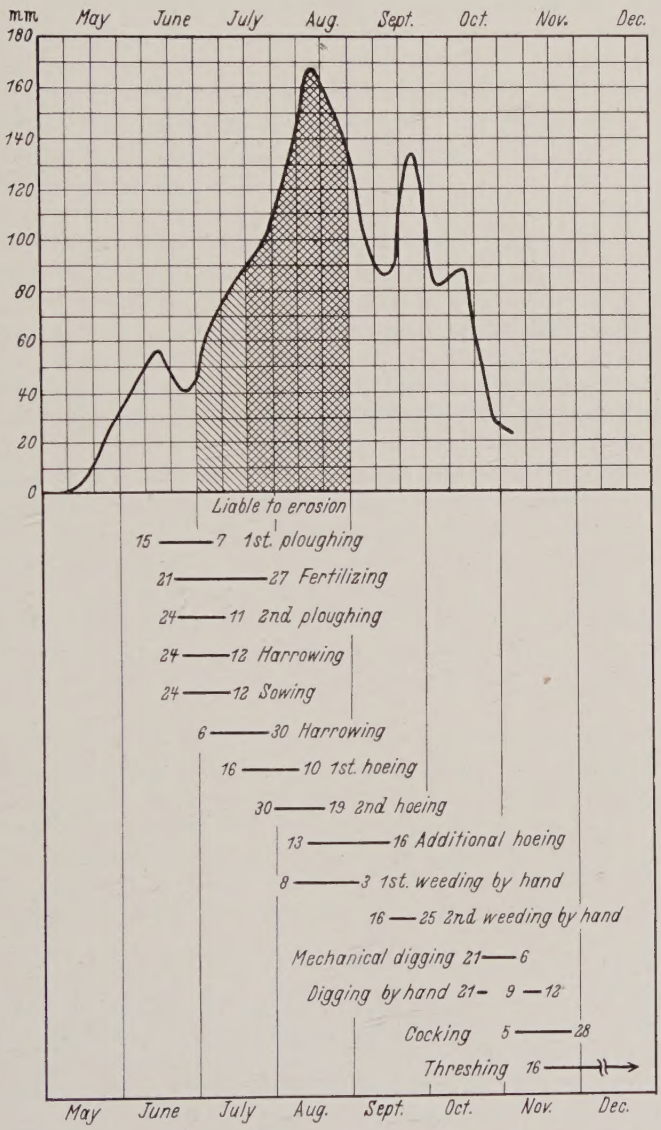


Figure 1. Cultural calendar: mean annual rainfall 1950–1953

Ecologically the area represents a special form of the French-Guinea savanna. The climate allows a forest growth averaging 350 trees, diameter 20 to 30 cm, per ha. In the tree and shrub layers, there are many

representatives of the species *Afrormosia*, *Afzelia*, *Albizzia*, *Bomba*, *Combretum*, *Cordyla*, *Daniella*, *Lannea*, *Parkia*, *Pterocarpus*, *Sterculia*, *etc*; *Andropogon*, *Rottboellia*, and *Shizachyrium* are predominant among the grasses. One of the grasses, *Pennisetum subangustum* Stapf and C. E. Hubb, unimportant in the original vegetation, became a rampant weed in the first year of development and caused the failure of a great part of the crop.

The development methods used followed the same lines as in the British ' ground-nut scheme ' in Tanganyika.

Work began in 1949 using bulldozers to push over the trees, a method taking 17 hr/ha. just to root up the trees, and ruining the equipment. In the second method the trees were pulled over by winches mounted on stationary tractors, taking 8 to 10 hr/ha. In the method finally developed as most economic for large areas, the trees were pulled over by a heavy chain, mounted between two tractors moving near together (chain clearing) and followed by a third (treedozer) to help with the most stubborn trees. This reduced the clearing time to 1 to 2 hr/ha. for each tractor. The total number of hours needed to bring the site to a state ready for cultivation dropped during the period from 50 to approximately 15 hr/ha.

Various heavy American tracked tractors and other equipment were used in clearing the forest, the Caterpillar D.8, Allis Chalmers HD 19, and International Harvester T.18 giving good results.

Clearing takes place during the rainy period, when the ground is well soaked and the roots can be loosened. The timber is then left lying until the dry season when it is piled in windrows and partly burnt.

Originally the area was cleared in strips 250 m broad and 1000 m long separated by strips of untouched forest for protection against wind damage. Three windrows of felled trees were necessary, two at the sides and one down the middle. Later the width of the strips was reduced to 200 m. Two windrows along the edges were then sufficient, with a corresponding saving in labour.

The remaining roots were cut to a depth of 30 to 40 cm by an underground cutter (root cutter) and loose fragments of wood were removed from the area by a ' root comb ' (rooter). Removing these fragments caused a good deal of trouble. Even now, after some years of cultivation, root fragments are still found in the surface soil, and they cause much damage to machines, especially row drills and ground-nut lifters. The ground was then levelled using an old caterpillar track drawn between two tracked tractors moving side by side.

The combination of soil and climate in this region make the soil very liable to erosion. As soon as the site is robbed of its natural protective plant cover, damage to the structure and loss of valuable constituents occur; if the first crop of ground-nuts after opening up is followed directly in the next season by a second, the yields are 20 to 40 per cent lower. The experimental station run by the C.G.O.T. at Séfa, under the leadership first of Ir P. Bouchet and then of his successor Ir R. Fauck, has devoted a great deal of attention to this subject.

The already low limit of 3 per cent originally established as the maximum slope for sites for development was later reduced to $2\frac{1}{2}$ per cent. On sites with a slope of $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent mechanical protective measures, forming

part of the concept of contour farming, were used but these were relaxed on slopes of 0 to 1½ per cent.

Of other measures used to protect the surface soil and to maintain its fertility, the regular addition of organic material in the form of green manure is the most important. The resulting improvement of the soil structure is of extreme importance in mechanization since it has a direct effect on the possibility of using the machines and on their output, *e.g.* in the mechanical lifting of ground-nuts.

Sample plots that had received green manuring could be harvested mechanically for ten days after the last rainfall, whereas unmanured control plots, because of quicker drying and hardening, could only be harvested during six days.

Green manure was originally applied in a three-year rotation, but is at present used in a four-year rotation with the following courses:

1st year: green manuring
2nd year: ground-nuts
3rd year: grain
4th year: ground-nuts

Of the many crops tried as green manure, *Sorghum vulgare*, which in favourable conditions can yield 50 to 70 tons green material per hectare, seemed to be one of the best.

The different operations in ground-nut cultivation on the fully mechanized management unit, UC1, are given in the cultivation calendar in *Figure 1* and the composition of the machine pool for this unit in 1953 is shown in *Table 1*.

Table 1. Composition of the machine pool UC1 in 1953

Tractor or implement	*Total No. in 1953*	*Working hours per tractor or implement in 1953**
International Harvester tracked tractor TD 9	6	836
Massey-Harris wheeled tractor 44	17	834
Massey-Harris disc-harrow 509 'One way'	6	393
Massey-Harris disc-harrow 26 'Wide level'	4	282
Massey-Harris Disc plough 605	6	267
Gougis fertilizer spreader, 4 m	2	414
Light weed harrow, 4 m	6	204
Gougis corn drill	1	?
Massey-Harris ground-nut drill 77	10	119
Nolle hoe	10	305
Massey-Harris Peanut Digger 115	12	220
*Nolle ground-nut lifter***	4	84
Frick thresher	5	631

* The planted areas in this unit in 1953 were: ground-nuts 1125 ha., green manure 490 ha., sorghum 20 ha., a total of 1635 ha.

** Experimental stage.

The first soil cultivation takes place as soon as possible after the first rainfall ($\geqslant$ 60 mm) using a 16-disc Massey-Harris 509 *One way*, drawn by a TD 9, to a depth of 10 to 12 cm. The purpose of this, in addition to facilitating cultivation, is to provide favourable conditions for rapid weed growth, so that the weeds can be destroyed by the second cultivation, using

a 30-disc Massey-Harris 26 *Wide level* to a depth of 6 to 8 cm. The only artificial fertilizer used up to the present is 38 per cent phosphate, applied at a rate of 100 kg/ha. between the two cultivations by a Gougis distributor with a 4 m wheel breadth.

The second soil cultivation is followed immediately by light harrowing, using a 4 m broad weed harrow drawn by a Massey-Harris 44, and then by sowing, using a Massey-Harris ground-nut drill mounted on the same type of tractor.

The strain of ground-nuts used at present is the commercial 28–206 from the Bambey experiment station, requiring a plant density of 80,000 to 100,000 plants/ha.

Figure 2. Green manuring, a conditio sine qua non *(reproduced by courtesy of C.G.O.T.)*

Planting in double rows, *lignes jumelées*, was found to give the best results for mechanical operations.

For this method of sowing, the four drill Massey-Harris maize planter No. 77 was slightly altered, and fitted with four extra seed boxes, seed tubes

and coulters. The paired rows lie 20 cm apart and the distance between the pairs is 75 cm; the quantity of soaked disinfected seed is 76 kg/ha., and the sowing depth 5 to 7 cm. In the Casamance project the ground-nuts are sown on level ground.

Weed control demands full attention as the rainy season continues. About two weeks after sowing, the light weed harrow already mentioned is drawn across the rows of young ground-nut plants, now strong enough to withstand this treatment. Then the four-row Nolle hoe (*polyculteur Nolle*) is used to hoe between the pairs of rows lengthwise. The strip between the two rows of a pair is hoed by hand.

The average time for these operations is given in the cultivation calendar, but some variation naturally occurs with amount of weed growth, weather and time available. There are different sets of hoe attachment so that it is possible, beginning with the second hoeing operation, to earth up the rows at the same time.

Mechanical harvesting of ground-nuts is a problem to which no satisfactory solution has been found in this area.

There is a steep rise in the yield curve towards the end of the ripening period, so that each week of too early harvesting means a considerable loss in production, while, on the other hand, the unworkable nature of the local soil makes it necessary to lift the crop early, before the soils harden like concrete.

The organization of the harvest depends for timing largely on agricultural 'feeling'. Immediately after the last rain of the season, which must be recognized as such, mechanical harvesting is started, and is replaced by harvesting with the native mattock (*n'daba*) when machine tools can no longer operate.

In the early years the Massey-Harris Peanut Digger 115 mounted on a Massey-Harris 44 was used for harvesting. It proved, however, difficult to handle, left many ground-nuts in the soil, called for much complementary work by hand and repeatedly damaged the crop. More recently it has been replaced by a French two-row chain harvester, the *Arracheuse d'arachides Nolle*, type *Duo*, which is much easier to handle, leaves fewer ground-nuts in the soil and can be used longer on drying soil.

In favourable soil moisture conditions, the *Nolle* harvests 1 ha. in $2\frac{1}{2}$ hr and the loss is only 5 to 10 per cent; harvesting by hand in such conditions takes 80 hr. The short time available for harvesting means that a large number of harvesting machines must be available. In 1953 because of the shortage of machines only a third of the 1,576 ha. planted could be harvested under favourable conditions, giving an average yield of 14·0 quintals/ha. The conditions on the other yields were so bad that the total average dropped to 11·6 q./ha.

After preliminary drying the harvested plants are gathered first into small heaps or windrows and then into man-high cocks at a density of 25/ha. and are threshed on the spot with a travelling ground-nut thresher (Frick Steel Peanut Picker) driven by a Massey-Harris 44, the ground-nuts being bagged up and removed.

No satisfactory solution has so far been found for mechanization of handling between harvesting and threshing, and the threshing of gleanings, if any.

Mechanical cultivation of the green manure and grain crops in the rotation causes no particular difficulties. The seed, mostly sorghum, is put in at the time of the soil cultivation, which is carried out only once, in the same way as the cultivation method used for the ground-nuts, after the first rain. The Gougis drill, mentioned in *Table 1*, is used, drawn by a Massey-Harris 44, for sowing the grain crop.

The seed for the green manure crop is sown, using the [illegible]d attachment obtainable with the Massey-Harris 509 *One way* disc har[illegible], drawn by a TD 9, in a single operation. By widening the seed tubes the seed can be sown more or less broadcast; this gives a better protection against erosion than drilling in rows.

The green manure crop is then left, until it is ploughed in to a depth of 20 to 30 cm, between the middle of August and the beginning of October, before the stalks get too hard, using a Massey-Harris 605 disc plough drawn by a TD 9. A horizontal angle iron is fixed in front of the plough to flatten the crop down.

It has already been mentioned that in favourable conditions, including fertilizing with raw phosphate, a production of 50 to 70 ton/ha. of green material can be obtained.

A new development in the important question of crop rotation is the possible replacement of sorghum among the cereals by a rice crop depending on adequate rainfall. Experiments have given extraordinarily good results and during the visit a very good experimental planting almost ready for harvesting, with an estimated yield of 20 q./ha., was seen.

The part of the concession at Séfa to be exploited in co-operation with native settlers is of a later date and comprises only a small area. An experimental colony of fifteen families on 60 ha. agricultural land was established in 1952. Its subsequent development is shown in *Table 2*.

Table 2

Year	*No. of families*	*Area*	
		Per family	*Total*
1952	15	4 ha.	60 ha.
1953	50	4 ha.	200 ha.
1954	78	4 ha. + *trial allotments of* 6 ha.	340 ha.
1955 (plan)	256	6 ha. + *allotments of* 4 ha. *for new or less able-bodied colonists*	1300 ha.

Up to 1954 an area of 4 ha. was allotted to each family, on condition that the tenant accepted in advance the crop rotation already described, as well as agreeing to the execution by C.G.O.T. of the necessary mechanized work against payment in kind. In future it is hoped to give good farmers a tenancy of 6 ha.

Draught cattle are not provided because the whole area is subject to trypanosomiasis. Trials are being made with N'Dama cattle, which seem largely resistant to the disease.

The crop rotation is four-yearly and corresponds with that on *UC1*. In the Sankoya settlement area which we visited, the forest had been cleared in strips of 200 × 1000 m and the individual allotments were laid out in each strip as shown in *Figure 3*.

The whole 200 m wide strip is cultivated mechanically, as already described, at the beginning of the season by C.G.O.T., and the 3 × 1 ha. of the individual allotment on which ground-nuts and grain are to be grown that year is handed over to the tenant. He sows, tends and harvests these crops with his own labour and native implements. The strip for green manure remains under the C.G.O.T. and the same equipment is used as in *UC1*.

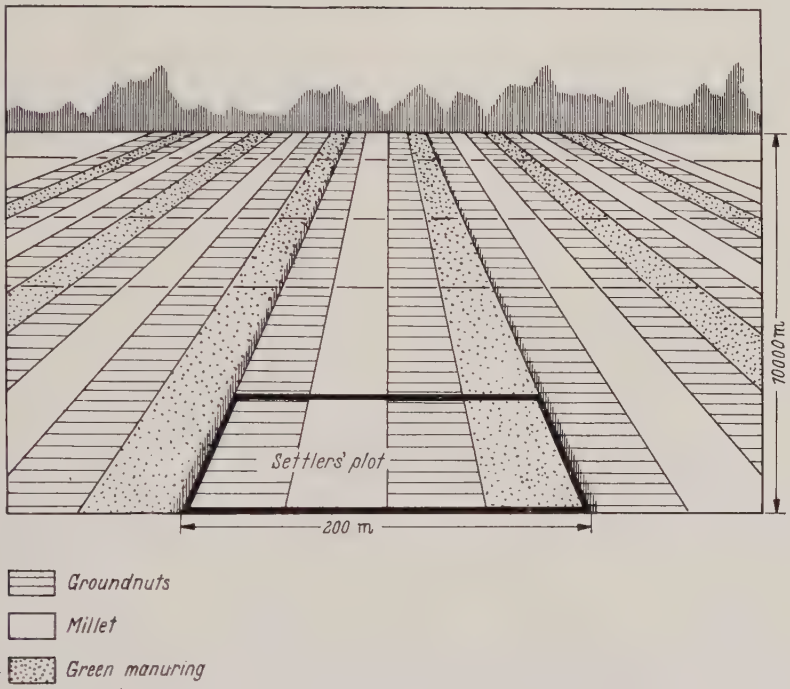


Figure 3. Plan showing division of land at Sankoya settlement area

CONCLUSIONS

The results on these semi-mechanized settlement areas are very satisfactory from the technical production point of view. In comparison with native ground-nut cultivation, with a production level of about 8 q./ha. per farmer, the average yield from the settlement at Sankoya on 100 ha. of ground-nuts was 16·9 q./ha. or 33·8 q. per farmer. After deduction of the cost of the seed and of the mechanical cultivation, calculated in kind and amounting to 250 kg and 3 × 320 kg ground-nuts respectively, this amounts to twice or three times the settler's financial investment. The result of the *culture en association* compares favourably with the completely mechanized cultivation on *UC1*, where the average yield on the part of the area harvested in favourable conditions amounted to 14·0 q./ha.

The economic and social advantages of the scheme are shown by the low rate of defection among the settlers, only about 14 per cent in 1953.

One may justifiably hope that under the leadership of Monsieur M. Guernier, the able and energetic director of C.G.O.T., and his fellow workers, this encouraging position will continue in the future and spread to greater areas.

(*Received November 1955*)

Queensland—A Tropical Curiosity

H. W. Herbert
Economic Services, Brisbane

The part of Queensland that lies within the tropics supports a population of 300,000. This seems a low density for an area of 360,000 square miles, but the great bulk of Queensland, and nearly all the rest of tropical Australia, lies within the ' dry ' tropics, where the relatively scanty monsoon rainfall permits only livestock ranching on natural grasses.

The best of these grasslands are in Queensland in a belt 200 to 400 miles from the coast, and in this tropical area some four million sheep are carried, with nearly three million cattle, mostly English beef breeds. There is scarcely any tropical significance in this stock-raising industry. The methods of stock husbandry and grassland management are not appreciably different from those of subtropical Queensland, or parts of temperate southern Australia.

The pastures in inland tropical Queensland are almost entirely summer growing. The soils of the natural grasslands are very fertile; no top-dressing is done, and no introduced grasses have yet proved superior to the native ones. These grasses make prolific growth in all years when at least one soaking rainfall is received. They rapidly run to seed at the end of summer, and the dry grass stands throughout the winter as a kind of natural ' hay ', which sustains sheep and cattle at low carrying rates (one sheep to three acres) until the next wet season. Winter rain is scanty, and is not welcomed in much of the area, because it lessens the feed value of the dry grass by leaching and by blackening it with fungus.

PRODUCTIVITY

In common with other inland pastoral areas in Australia, the productivity per worker in the inland pastoral belt of tropical Queensland is exceptionally high, higher even than it is in the majority of manufacturing industries in North America. This is due to a combination of circumstances. Natural resources are excellent—good grasslands overlying the world's largest artesian water basin that gives ample stock water, and the semi-arid climate making it possible to breed fine-wool merino sheep in the tropics with relative freedom from disease.

The skill and assets of the property owners and their employees are equally important and have been accumulated over several generations, including high wool-yielding and robust sheep, labour-saving capital improvements of fencing, drafting yards and shearing sheds, stock water points and well-equipped homesteads. Selection to improve the quality of sheep, cattle and riding horses is being constantly practised. A number of disasters must be guarded against—grass and bush fires, drought, floods, outbreaks of disease, and blowfly strike of sheep in humid weather (for the latter new insecticides are proving very effective). In most of the rougher country

between the interior grasslands and the coast wild dogs and cattle ticks are serious pests.

On a well-equipped property where one man can look after, with seasonal assistance, some 2,000 sheep, which each yield 8 lb. of wool, worth currently 4*s** per lb., this means a gross income of £3,200, and a net income to cover labour and interest on capital invested of well over £2,000 per annum. However, the total capital investment per worker might be as high as £20,000, which would absorb nearly half the net income in interest charges.

Until the last few years there was no agriculture in the inland pastoral belt. A highly uncertain, mainly summer, rainfall of 15 to 20 in. year did not encourage it. In spite of the high risk of crop failure a few graziers have recently been growing saccharine sorghums for fodder conservation as ensilage.

The crop is mechanically harvested and ensiled in bulldozed earth trenches. Graziers adopting this ensilage making usually aim to store enough in good years to feed only their best stock in time of drought. How to save all the stock in a bad drought, which lasts for a year or more and might be expected approximately once in ten years, is a problem with no definite solution. Once a grazier starts hand feeding (with grain or concentrates) in a drought he soon comes to the point where he cannot afford to stop, he has invested so much already in keeping the stock alive. But before the drought breaks he may have piled up a mountainous debt, which will take many years, plus good luck with seasons and prices, to pay off.

Agriculturally, the grazing of the inland and the crop growing of the Queensland tropical coast are completely different. The rougher timbered country that lies between and carries beef cattle has most of its affinities with the inland grazing industry, although it extends in many places to the coast. The cattle grazier rarely does any farming; he is a toughened horseman who with half a dozen employees may have to muster 5,000 cattle over a timbered property of 200,000 acres with few fences. By contrast the most common size of a sugar cane farm is 50 to 70 acres, nearly all cultivated and usually worked by the owner.

Yet in a country like Australia with no economic boundaries, conditions in one industry influence another. Australian rural labour is fairly adaptable; some cane-cutters are capable of transferring to sheep shearing or cattle work. They belong to the one employees' trade union (compulsory in Queensland) and their wages are fixed by the same Industrial Court to yield, for comparable skill and arduousness of work, very similar pay. A good shearer can earn £30 to £40 per week during the season, and so can a cane-cutter (who cuts and loads eight tons of cane a day). Both jobs are on piece-work rates and allow for the work being seasonal. Weekly wages for year-round employment in sheep, cattle or sugar industries are under half these rates but there is greater security and less strenuous work.

Since 1941 there has been, except for one year, a continuous labour shortage in Australia, arising partly from heavy programmes of capital construction throughout the country, and from inflationary pressures. Immigration at a heavy rate (postwar migrants are now 10 per cent of the

* All prices quoted are sterling

population) has not alleviated the labour shortage because it has encouraged further capital investment projects.

Rural industries are overcoming gradually these postwar conditions of chronic labour shortage. It has been less difficult for the grazing industry, which has always had a small employment for its output, and valued skill far more highly than numbers of employees. In the grazing industry the main effect of the labour shortage has been to make it difficult to have capital improvements, such as fencing, carried out except at a very expensive rate (£150 per mile for a sheep-proof fence at present).

Although the sheep and cattle grazing industries have been extremely labour-saving, the truly tropical agriculture of the Queensland coast has not. Its origins and traditions have been quite different. Sugar cane has always been the industry of overwhelming importance on the tropical coast; in the last two years about eight million tons of cane have been cut annually, about 80 per cent of Australian production. Before 1900 cane growing was a relatively cheap labour industry, and thousands of South Sea islanders (Kanakas) were indentured to work in Queensland canefields. They were later repatriated, and the sugar industry had a difficult time for many years, struggling to improve its growing and milling efficiency to operate with Australian labour at normal Australian wage rates and maintain farmers' incomes, which, on world standards, have always been high.

The Australian farming pattern in general has been one of owner-farmers who do the manual and machinery work either alone or with sons or one or two employees. In the paddock the farmer and his employees are often indistinguishable in appearance, speech, or in the work they are doing.

Wheat is Australia's major crop, and it has been fully mechanized (first with horse teams and later with tractors) for 100 years. Wheat has set the pace for labour-efficient agriculture in Australia; one farmer working alone can cultivate, sow and, with some temporary assistance, harvest a crop of 500 or more acres. Generally speaking, the more hand-labour an Australian farming industry has required the less it has prospered, and the more it has looked for political assistance in the form of protection against imports, home price schemes, or subsidies.

RECENT DEVELOPMENTS

This situation has given great impetus not only to the use of machinery but also to scientific research and better farming methods. Progress in these directions has differed widely in the different farming industries. Wheat, barley and oats, have had the most success, extending over a long period. An imposing number of wheat farming inventions originated in Australia. It is not generally known that a series of wheat harvesting inventions have been developed in Australia in the last 120 years which not only solved the problem of harvesting light crops economically, but which were entirely independent and on different principles from the series of contemporary American inventions, begun by McCormick, which evolved into the combine harvester. The heavy American machine could not have worked successfully on much of the Australian pioneer wheatlands.

This subject is of interest to tropical agriculture because it shows what can be done by a relatively small farming community with a good degree of mechanical aptitude, under economic pressure encouraging initiative and invention. There is in Australia an interesting parallel between wheat harvesting development and present attempts to devise a successful mechanical cane harvesting and loading system.

The Australian system of mainly individual cane farms cutting some 50 acres precludes the use of the very large mechanical harvesters of Hawaii and Louisiana. In addition, Australian sugar mills, with one exception, have no cane laundries, and many of them would find it difficult to obtain enough water for a laundry. The exception is one of the two remaining 'plantations', Fairymead in south Queensland. (This Company has done much work on mechanical harvesting, and cuts and loads the bulk of its own cane with medium-sized cane harvesters and loaders, developed by the company or in the adjacent Bundaberg district.)

There is now a fervour of interest and invention in mechanical cane harvesting and loading in Queensland. Some efforts in this direction were made nearly 30 years ago, but the relatively plentiful hand-labour of the depressed 1930's caused interest to languish, as also did the supply of immigrant European labour in the late 1940's and early 1950's. The high and increasing cutting and loading output of Australian and European labour have kept down the cost per ton of the relatively high wages that had to be paid. In the last two seasons however, there has been an absolute shortage at times of cane-cutting labour, and cane-cutters have often been able to earn well above the award minimum rate (12*s*/ton) for any crops difficult to cut. All cane is burnt before cutting, but even in tangled crops cutters have received as much as 30*s*/ton.

With every sign of some degree of labour shortage continuing in Australia the inducement to solve the mechanical harvesting problem is extreme. Yet under Queensland conditions it is not an easy problem to solve. The ideal machine should be small enough to work on existing individually-owned cane farms, and cheap enough for farmers to buy. It should be able to cut all crops except badly tangled ones. In this regard cane breeding will gradually be able to produce varieties which are very resistant to lodging, but this will be a slow process, and in years of bad winds some tangled cane can still be expected. The machine should be able to deliver reasonably clean and well-topped cane. Present standards of hand topping are low, due to the recent practice of topping on the ground, and it should not be difficult to do as well, or better than this by machine. Some Queensland machines are approaching these requirements.

Ideally, a machine should be able to load directly on to tram trucks (or other forms of transport to mill) without dropping the cut cane on the ground. So far nearly all effort in Queensland has been on the lines of a cane-cutting machine dropping bundles on the ground and a separate mechanical loader subsequently picking up and loading the bundles. This results, particularly if the bundles are small, in a good deal of trash and some dirt and stones being picked up with the cane and consequent wear and damage in sugar mills. To devise a light-weight combined mechanical cutter and loader, which will operate with the existing transport system

(mainly 2 feet gauge tramways) is doubly difficult, but it can be forecast with confidence that it will be achieved in Queensland.

Excluding harvesting, all other work in cane farming has been completely mechanized. On the 5,000, or more, cane farms in tropical Queensland there is probably not a single horse-team left. Hand hoeing is rarely done today. Implements are increasingly tractor-mounted, many being of local design. With the improvement of tractors and implements that has taken place in the last 10 years, it was found that the smaller farms, harvesting some 30 to 40 acres of cane, were rather smaller than one man could handle with a set of modern farming plant.

FARM SIZE AND LAND OWNERSHIP

When Queensland cane acreages were increased recently some of these farmers obtained additional areas, but many of the smaller farms are hemmed in by neighbours or unusable land, and building up areas to an optimum size has only partly been achieved. Similarly, for mechanical harvesting it would be desirable, but not always possible, to redesign many of the individual holdings and the cane tramlines.

The loss of efficiency from the relatively ' frozen ' pattern of individually-owned freehold farms will not be great, but it is a problem that would not arise under the plantation system. Looking farther afield than Queensland, it is probable that a trend towards individual ownership of land will gradually take place in other cane-growing countries, as the education and mechanical capability of canefield workers improves, and as native populations seek greater political independence. One lesson to be learnt is that with mechanical progress taking place rapidly it is desirable to retain a degree of flexibility in the size and pattern of individual holdings. The area that appears to be the maximum a native farmer can handle today may prove far too small for his better-trained and more capable son, with the implements that will be available in 15 years' time.

These considerations would favour continued employee cane farming, or fairly short-term tenancies. Yet Queensland experience strongly indicates that land ownership by the working farmer is an incentive for which there is no substitute. It is largely responsible for the rapid application in Queensland cane farming of improved cultivation methods, pest and disease control, and the lifting of the sugar yield per acre from $1\frac{1}{2}$ tons in 1900 to 3 tons today. Cane growing in Queensland has, during the last generation, been in that happy degree of moderate prosperity which provides enough profit to allow the farmer to purchase better equipment and adopt better methods, but not so prosperous that he can sit back with unchanged methods and make an easy living. Although the average cane farmer has had no more than a primary education, and the older generation lack any formal training in agricultural science, the combined effect of over 5,000 working cane growers taking a keen interest in new developments in the industry is very great. It is a sufficient body of intelligent industry-opinion, when combined with the experts in agriculture and technology, to make fast progress under its own steam.

These advantages cannot be claimed to any degree for the rest of Queensland's tropical agriculture. These minor industries are maize

growing, dairying, tobacco, peanuts and various fruit and vegetable crops. Most of them are rather backward outliers of industries which are more advanced in overseas countries. They exist mainly to supply a local demand for the produce, or because they have obtained political support, such as the requirement that a percentage of all tobacco manufactured in Australia be Australian grown. Such a situation is not unique to Australia. Political lobbying often pays better, from the industry's narrow point of view, than the same amount of effort spent on improving its own efficiency.

In general it is the inescapable requirement of a large quota of expensive hand labour that retards these minor tropical industries, offsetting the value of favourable soils and climate. Some progress has been and is being made, such as the efficient use of tractors for all cultivation work, the use of milking machines, and better crop and pasture management methods.

Compared with cane growing, progress is much slower in these minor industries. It seems that this must be accounted for by the relatively small size of these industries (limited in the first instance by the areas available, or the size of markets, or the hand labour requirements). This prevents their growth to a size where specialization of expert knowledge and skilled practical application can reinforce and feed on each other, as with Queensland sugar, generating a body of capital in the form of skill and equipment on which rapid progress depends. It is probable that the tropical sheep and cattle grazing industry could not have developed to its present extent had it not been part and parcel of the vast grazing industry of the rest of Australia, facing similar problems and adopting similar methods.

(*Received January 1956*)

Agricultural Surveys with Particular Reference to Tropical Forest Conditions

W. H. Beckett
Senior Lecturer in Economics of Colonial Agriculture, Oxford University

S. L. Anyane
Department of Agriculture, Gold Coast

The set of problems usually dealt with in textbooks and articles on agricultural economic and sociological survey, and to a large extent in reports of surveys, is different from that which confronts the field worker in the planning and organization of a survey. Standards demanded by the observance of sampling theory, for example, have to be subordinated to the limits imposed by actual physical conditions. This article is primarily concerned with the latter problem, the difficulties in conducting surveys in tropical forest country and with illiterate farming communities.

The article developed from discussions between the authors, the one a past and the other a present member of the Gold Coast Department of Agriculture. *Parts I* and *III* are based mainly on lecture notes used by W. H. Beckett at Oxford in connection with Oversea Service Courses, and the examples in *Part II* from the field experience of both authors and of another former Gold Coast officer, James Gordon. Many of his ideas put forward when serving in the Gold Coast or later, during study leave in Oxford, find expression in this paper.

Part I

The primary purpose is to provide a fund of recorded knowledge from the experience of the farmer of the processes on the farm in order to facilitate development. This knowledge will cover the elements, determinants and indicators which are necessary to describe and understand the static and dynamic nature of the economy.

At the present stage of development in technique, surveys will be partly experimental and constitute research into method, as well as being pieces of applied research. In practice however, in the rapidly developing economies of the tropical zone, the emphasis must be on the practical problems demanding attention. The surveys will be, as described by an Indian writer, 'explanatory diagnostic' rather than 'exploratory academic', and will stem from a desire to plan development and lead to immediate action programmes.

Procedures may be broadly classified into census, survey and case study. These methods are not mutually exclusive and no one can be the universally optimum method. They will in practice merge and any particular field

study will probably contain elements of each method, although preponderantly following one of the three. When this is the case the secondary methods will be complementary to the main method used. Choice will depend on the scope as well as the nature of the enquiry, whether it covers all or part of the population, or the whole or part of a complete process in time. This paper deals with the survey method.

COMPREHENSIVE QUESTIONNAIRE

Many attempts have been made to set out comprehensive questionnaires or schedules covering the whole economy. One approach might be to use main divisions covering history, ecology, demography, general economy and sociology, each being sub-divided. Examples of the broad picture are provided by the Nuffield Questionnaire for the Study of Native Economies, the F.A.O.'s *Essentials of Rural Welfare*, or the International Bank Reports on different countries. The broad classification could be made in several equally satisfactory ways. It is, however, a useful discipline to conceive the particular investigation as part of this complete picture. Moreover, an accepted classification by all countries, at the instigation of the United Nations, would facilitate comparability and increase the usefulness of published reports. An accepted framework for British territories is long overdue. It is of course important to preserve some balance between uniformity and flexibility, between the comparability of different surveys and the adaptability of the framework to local conditions. All surveys are limited by conditions and people as they are, and not as the investigator might wish them to be.

NATURE OF THE PROBLEM

Successful survey demands mutual respect of surveyor and surveyed. Technical efficiency is a poor substitute for sympathetic understanding. The process from conception to final report may be divided into four broad stages, termed for convenience (*1*) formulation, (*2*) enumeration, (*3*) tabulation and (*4*) evaluation. It is useful at the planning stage to test the prepared scheme by subjecting it to the planning procedure of a military campaign—intention, information, method, administration. This is particularly useful in imposing a check on the collection and analysis of information which may already have been assembled. Unfortunately many surveys carried out by enthusiastic officers in the administration or technical departments, as more or less private ventures, are for lack of a little expert guidance partly wasted effort. Other useful material never reaches the report stage, or if it does is lost in a departmental file. Some organization for listing these and preparing abstracts is very necessary. The new university colleges and research institutions, embarking on research projects, are often unaware of this buried material.

Formulation—The first stage is to write down concisely the aims and objects of the survey, and the broad plan for its prosecution. The second is the preparation of lists of likely sources of information, suggested schedules, maps, forms, personnel, equipment for office and field, including transport, a rough budget, and a timetable. These will then be discussed with interested parties, criticism and comment being invited and their assistance or collaboration sought where necessary. The third stage is the assembly of all the

existing information, preparation of detailed schedules, *etc*, design of forms to be used including organizational charts and flow sheets, indents for needed supplies and equipment, and arrangements regarding staff recruitment, pay, conditions of service, *etc*. If there is not already an adequate background of local knowledge and expertize, a pilot survey may be necessary.

The next stage is the actual recruitment of senior staff and skeleton field staff, the preparation of instruction sheets for each class of worker, and a ' trial run '. For this trial run the team will be very high-powered, consisting of the available personnel, the majority being senior staff. Deficiencies in the organization will show up and the necessary amendments and changes can then be made. The final stage in the formulation is the perfection of the organization and the expansion to full-scale survey.

Enumeration—Field work will be preceded by the necessary assembly of the human and material resources required to carry out the survey. Where a systematic training scheme has been decided on, it is advisable to begin the survey with one team which will gain experience and form the nucleus of the training staff and of future teams. Training will be required in pacing distances, recording areas by the methods chosen, use of maps and forms, and in gaining experience in eye estimation and counts.

Supervision and checking of field workers' results, on inspection by a survey officer, cannot replace systematic routine checks. The maintenance of uniformity in observation is important and difficult, and some rotation of personnel between teams or the employment of certain field workers as calibrators moving from team to team, may be unavoidable. The alternative is an unduly large proportion of the supervisory officer's time being devoted to this work.

Some of the existing sources may be used for current information during the survey: railway onloadings, road checks and market data may provide direct checks for a production survey. Indirect checks may be useful: petrol sales against aggregate transport costs, firms' purchases against farmers' sales, market tolls against produce, *etc*. Indirect help may be obtained from schools. Police may arrange to inspect lorries for licences or overloading at a point convenient for a survey officer to take a record of produce passing, where no statutory authority exists for recording produce. Organizations such as lorry drivers' associations will be flattered by being consulted and prove most cooperative in instructing their members to provide all information and assistance to a survey officer.

Much information, outside the prescribed survey data, will interest field officers and they should be encouraged to keep a field diary. It serves to bring to light problems which merit investigation.

Useful field techniques are far too numerous to be dealt with here, and one point only is included—enumeration by a pair of observers. Two observers, starting from a farm boundary, moving alternately in short distances along parallel lines in the same direction, and counting how many trees pass between them, can both make a separate eye count quite accurately. An adaptation of this technique can deal with moving populations such as herds of cattle.

Two observers can make a rapid and accurate offset plan of a field by

first selecting a centre line. Then the first paces to the boundary on one side, along the boundary until he is opposite to the second man who has moved ten yards along the centre line. The second man then performs a similar operation on the other side and the process is repeated until the farm is completed. In this way offsets are paced at ten yard intervals on each side of a centre line, and kept at right angles without difficulty as one observer returning from a boundary can see the other observer marking the spot on the centre line. A simple addition of the offset lengths and a division gives the area.

The click counter, the pedometer, the cycle wheel mileometer are cheap and useful adjuncts. A compass, a chain and a whistle form an effective combination for rough mapping in dense undergrowth where it is difficult to see.

Tabulation—This consists of receiving and filing all returns, summation and analysis of data, computation and preparation of summary tables for report, and preparation of charts, maps, *etc*. Though this is mainly statistical, the routine administrative duties covering issues, supplies, payments, *etc*, can conveniently be placed under the same control, making the office section an integrated whole. The key to efficient office work is system, standardization and classification. The system will depend on the size and scope of the survey and the speed with which results are required. One criterion should be that one set of returns from the field, whether weekly or monthly, is completely dealt with before the next batch is due.

Loose leaf filing, with standardized holes and standard sizes of paper, as quarto (10 in. × 8 in.), foolscap (13 in. × 8 in.), *etc*, and standard filing cards or postcards should be used. Every sheet requires a blank margin for filing, and should be used on one side only. Some proprietary loose leaf binding will be required as a basis, but cheap satisfactory loose leaf files can be made from cardboard file jackets, using a hand punch, paste and round shoe-laces. Mechanical aids—typewriters, adding and calculating machines, punched card systems—are a great asset. The design of the forms and record sheets will depend on the aids available. Where a mechanical card system is not in use, arrange tabulation, distributions, *etc*, as far as possible in two separate series such as districts and months, or age classes and places, so that totals and means are arrived at in two different ways and so become self-checking. If all forms used have a stock number and columns (or rows) are numbered, the source of all derived and summary data can be indicated in the column heading, by a simple number reference. For example, yield-per-acre data, calculated from acreage given in column 5 of form 05, and production given in column 2 of form 13, would be indicated by 13/2÷05/5. The actual classification, whether decimal, letter or other, is not important, provided it is an exact classification.

The Report—It should aim to give a reader, in the shortest time, an understanding of the aims and objects of the enquiry, the important results obtained and the conclusions drawn. This will demand concise writing and full use of simple clear maps, diagrams, plans, graphs and summary tables. The location and the period concerned should be seen at a glance. The author's own appraisal of the validity of the results should be given. The main report should be confined to the terms of reference, and the inclusion of

suggestions for action programmes will depend on the nature of the report.

Statistical material, detailed maps, full reports on special enquiries, and information outside the terms of reference should be given in appendices. One appendix should give details of administrative aspects such as staff, methods, copies of forms used, schedules, and costs of survey items.

A report which is necessarily long should have a full contents page and short summary at the beginning, and a full index at the end. The serial numbering of paragraphs is an advantage.

The most difficult and dangerous part of the report concerns inferences and conclusions. The interpretation of facts is not easy, and it is necessary to beware of accepting statistical significance as evidence of causal relationship.

Part II

EXAMPLES OF SURVEYS

Route survey—A reconnaissance was carried out in 1944 to find swollen shoot disease in cocoa farms in closed forest country. The farmers are mainly village dwellers and the farms extend from the village to upwards of three miles. Villages are linked by bush paths. Planting is irregular. The 1 in. field sheets issued by the Survey Department are excellent. There is no registration of titles of farms.

The survey was designed to include a visit to every village and provide linear records on paths radiating from the village, as far as possible orientated at four points of the compass, the actual directions depending on the main paths between villages. Survey teams recorded distances in ten-yard units from the village centre to the boundary of the village, and of cocoa cultivation and other crops to the periphery of the cultivated area, continuing certain records of types of vegetation, dominant forest species, *etc*, between villages. A number of factors were recorded for each change of vegetation, those for cocoa including age, spacing, sanitation, canopy, pests and diseases, *etc*. Every item was coded. Simple summation gave complete distributions of age class, incidence of particular pests and other factors. Monthly reports were prepared for the 15th of each month, containing the complete period and aggregate analysis of all data collected up to the end of the previous month.

The 1 in. maps were enlarged four times by photostat. The maps have à 5′ (five minutes = geographical mile) grid. On the photostat this 22 in. ($5\frac{1}{2}$ statute miles approx.) square was divided into 2 in. squares equivalent to 880 yards, and a transparent grid of 16 divisions used on this square to define any point on the ground to within 55 yards. By this method a point was defined by a 4-rank formula, and with landmarks such as a fallen tree or rock outcrop enabled a research officer to find a disease outbreak in a farm in forest country without a guide.

Other information, agricultural, economic or sociological was recorded for villages at which parties spent the night. Key villages were completely surveyed, every farm being mapped, every path surveyed on the standard method, and data from different sets of four paths compared with the known distributions from the complete survey. Farms tended to follow ' ribbon ' planting and density tended to diminish with distance from the village.

Where swollen shoot was found, either during the standard observations

or from information received, a special investigation in more detail was made. Although finding virus disease outbreaks in peasant farms in forest country is rather like finding needles in a haystack, subsequent complete large scale surveys have proved that the reconnaissance was 100 per cent efficient in finding even scattered outbreaks.

The final maps produced no record of actual farms but defined within the area surveyed the limits of cocoa cultivation around each village, uncultivated forest areas and the non-agricultural village area. The representation of the linear records along the paths on the maps was necessarily diagrammatic and gave visual impressions of distributions.

Cobweb—More intensive surveys were conducted on the cobweb principle. Paths surveyed were divided into half-mile sections (by measurement and from the map), and surveys were then made along compass traverses between paths, thus completing a series of concentric ring surveys. This required much more time in conditions where traces had to be cut, but it formed a useful compromise between the route survey and the complete farm enumeration.

Relay—A field technique developed by S. L. ANYANE for the systematic completion of a cobweb pattern, is as follows. The survey party is divided up into teams of two or more men. Any one team surveys a path from the village as far as the first concentric ring, turns left making a compass traverse until it reaches the next path, continues along that path until the next concentric ring is reached, and so on to the limit of the cultivation, returning to base direct down the last path (see *Figure 1*).

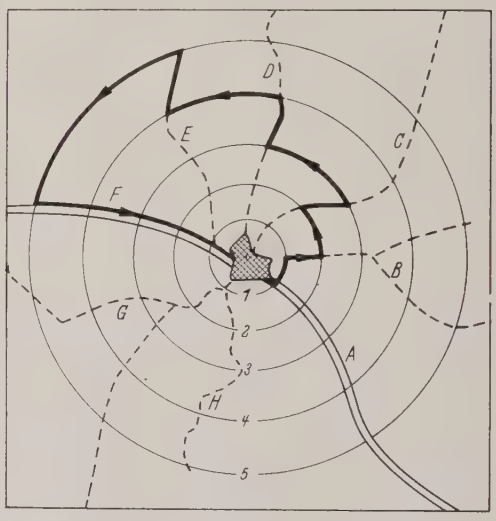


Figure 1. Relay survey with cobweb pattern. Course taken by team A: A1, B2, C3, D4, E5 returning by F; course taken by team B; B1, C2, D3, E4, F5, returning by G

Village area

Roads

Paths

Route taken by one survey team, beginning on path A

Teams are picked to walk the relay according to the number of important paths leading from the village. The concentric ring intervals depend on the density of the cropping and may be greater further from the village. The team records samples at agreed intervals and of agreed area along the paths and arcs of the concentric circles. During the return walk to base, checking is carried out; each team thus checking another teams' observations. At each ring–path intersection, a baton is fixed by the first team so that at the end of each compass traverse the next team to the right will have it as a guide, on emerging on to the new path.

SURVEY AS A METHOD OF FIELD EXPERIMENT

The survey method is a useful but neglected alternative or complement to agricultural field experiment. This applies particularly to tree crops and to cultural factors such as spacing, ridging and time of planting. In tree crops in peasant practice planting is frequently random (irregular). Spacing experiments carried out on an experiment station will be regular in pattern, limited to a few different spacings, a few soil types and other conditions, and will take several years before any tentative results are available and at the best be atypical. Results may be statistically significant but only for the conditions of the plantation and may not be applicable to the peasant farm.

By selecting a large number of plots in existing peasant farms, recording all the relevant characteristics of the farms at the first visit and using calibrated eye estimates for yield, the effect of spacing (tree counts per unit area) and also its interaction with age, soil type and other factors can be ascertained in one season, for the particular climatic conditions of that season. Moreover the results are applicable to the peasant farms. To have any chance of successful adoption by peasant farmers, an improvement must not only be one in fact but must also be an obvious improvement. In most cases it would be true to say that if the result of a treatment was of so small a magnitude that a correctly designed experimental layout was required to detect it, the treatment would have no appeal to the average peasant.

Another example may be taken from planting times. Experiment station plots can only cover a limited number of conditions in one season, but the recording of planting data from a large number of farms, either by travelling observers or by staff engaged on other duties can be followed up by some method of estimating yield at harvest. The cost by such methods is very small, the main requirement being simple but efficient organization.

Part III

SOME PRINCIPLES, PRACTICES AND OBSERVATIONS

1. The whole survey should be planned down to the report stage before the main work begins, including pro-formas for the tables to be included in the final report. Where this is impossible, a trial or pilot survey should be made.

2. Each member of the survey team of whatever rank, including the director, should be capable of doing, and have actually done, all the operations required from the staff working under him. It is useful to adopt the

method of time and motion study, and record in the first instance the times taken for each operation, both in field and office.

3. Issue exact written sets of instructions for each rank of field worker. Use organizational charts and flow sheets in the office. The test of the efficiency of the organization is whether an average person conversant with survey procedure could take over any part of it, without further instruction from another person.

4. Collect the maximum amount of information within the competence of the personnel and the limit of expenditure. Travel is a large item, both in time and cost; doubling the information, by intensifying the survey, may add very little to the total cost. One very simple questionnaire becomes monotonous; additional work demanded from field staff may lead to increased interest and efficiency.

5. The provisional scheme should be submitted for comment to all possible interested parties and suggestions invited for collection of data for their own purposes, which might be grafted on to the agricultural survey without serious disruption, *e.g.* a route survey of farms can at the same time include dominant forest trees; gate checks for agricultural produce can also record traffic or persons, timber and charcoal, data useful to the administration, the police and the forestry department.

6. Travelling field staff must sleep somewhere. They will automatically and unconsciously make observations in a village—quality of water, distance of bathing place, type of latrines, houses, *etc.* This can be recorded and provide valuable sociological information, with no extra cost.

7. A separate special enquiry which a team member can make, as his own personal piece of research, is a valuable morale factor, *e.g.* diet study of households in which he lodges during tours; a sociological factor; specific aspects of husbandry.

8. Absolute integrity is an essential requirement in the collection and handling of data; petty dishonesty with travelling claims, for instance, is insignificant in comparison.

9. The office side is less glamorous but more exacting. If possible, alternate field and office staff so that at least a portion in either section knows the other's difficulties.

10. In a large survey, conduct a regular training course, and where expanded over a period of time, expand by dilution so that fresh field workers join already experienced men.

11. Don't despise illiterate or near-illiterate workers. They are generally superior to and more reliable than more educated field workers for the routine monotonous jobs such as tree counts.

12. The grid system and code used to define a particular farm, from the coordinates of the available map, should be such as to allow an intelligent observer to find it without the services of a guide.

13. Reduce all records, except in special cases, to code numbers and letters. This is effected by producing ' possible answers ' to all questions and coding them. One foolscap sheet, with efficiently designed rows, columns and code, will record 15 separate facts for 30 separate farms. Avoid

the ' cross-out-whichever-does-not-apply ' form; the waste of ink and paper in the repetition is great, and tabulation is much more tedious and difficult. Have the code key pasted on the backing plates for easy reference by the field worker.

14. The design of forms is the most difficult and probably the most important part in planning a survey.

15. Every field record sheet should be serially numbered and returned to headquarters. A spoilt sheet may be copied, but the original spoilt sheet must be cancelled and returned with the copy. If any summation is done by the field observer, it should be done at the close of each day's work. One sheet of narrow ruled foolscap paper (13 in. × 8 in.) or 1/5 in. squared paper, with columns numbered 1 to 50, 51 to 100, 101 to 150, *etc*, serves as a check sheet for the return of 1,000 records.

16. Avoid as far as possible statements which require weighting before they can be totalled, *e.g.* percentages. If a percentage statistic is derived from an enumeration, the actual numbers are easier to handle. If it is not, but is an eye estimate, no accuracy will be sacrificed by chosing a fixed number of categories into which each estimate can be fitted.

17. Each routine checking should be made by repetition without recourse to the original observations. Let a field worker or gang repeat a series on another day, or let two make the same observations separately.

18. Field record sheets should be bound in books, in duplicate. Use a carbon, a ball-point pen and a hard backing sheet, so that an impression of one record does not appear on the next. The original should be detached from the duplicate and never sent by the same messenger or post.

19. Every record sheet should indicate *who*, *when* and *where*, and if not otherwise indicated, *how*: that is, the field worker concerned, the date and the place. Every worker and place should be given a code number; this saves space and time and makes records more exact. All original data should be filed.

20. All maps should show the coordinates, latitude and longitude. All tables should give the date or period to which they refer. Graphs, diagrams, *etc*, in the report should be simple and not overburdened with detail. Their purpose is to give a visual impression. For detail, reference can be made to the original and summary data.

21. All data from the field should be analysed as received, and transfers to summary tables or maps and graphs should be made concurrently with the progress of the survey. Monthly reports should be prepared showing progress to date and summaries to date, irrespective of whether or not they are required for external use. The monthly report is the Survey Director's watchdog.

TERMS AND DEFINITIONS

Data—The records taken by or provided for the observer, form the original data. Derived data are obtained from this, *e.g.* percentages calculated from quantities, or yield per acre from area and crop data. Summary data are obtained by the summarization and analysis of the original and derived data, and provide the final statistics for the report.

Frame—The population which is already listed, or known to exist and to be recordable, from which the sample to be observed and enumerated can be selected, *e.g.* lists of villages, lists of farmers in a village, or areas defined by coordinates on a map.

Questionnaire or schedule—Primary for replies, either written or verbal, by the individual and secondary for replies by the observer, or field worker, recording data supplied to him by others, or derived from his observations and value judgments.

Sampling—Selecting the individuals to be studied. This may be purely ' random ' or completely ' systematic ', or a combination of both.

Stratified sample—Sampling, by random or other method, inside ' homogeneous ' groups into which the population has been divided, *e.g.* farms in different size groups, or different soil types. The size of the sample from one group may vary according to the number and the heterogeneity within the group, the aim being constant precision. Stratification may be simple or multiple, having one or more stages and taking account of one or more factors. Multi-stage or sub-sampling is useful with correlated characteristics, the one observed at a lower stage than the other, thus reducing the volume of observation required. Allied terms used are ' restricted ' and ' controlled ' random sampling.

Cluster—A group of units in one of the selected areas, *e.g.* a group of villages, or households in a village, or farms.

Constant precision—The error, and therefore the precision, being of the same order of magnitude, within and between strata. There is then no waste through taking too large a sample in some parts of the population. Maximum information for a fixed cost, or minimum cost for the information required.

Census—A complete enumeration of every unit in the ' universe ' or ' population ' studied. May cover one or more attributes or characteristics of each individual unit, *e.g.* farms, animal population, *etc.* In practice, failure to obtain information from some of the units results in a ' partial census '.

Case study—A study, generally detailed, of one unit in the population, *e.g.* one farmer or one village.

Survey—(*a*) A land utilization survey may record the size and use of every piece of land in a village, district, *etc*, generally with the idea of producing maps. (*b*) Survey may denote a ' sample '—a recording of groups of selected units in the population, to reduce the volume of statistics.

An *intensive* survey approximates to a census, recording a large proportion of the population, generally in a small area. *Extensive* survey covers a wide area and records a small proportion of the population.

A *comprehensive* survey aims to record as complete description as possible of all attributes and characteristics of the population. A *narrow* survey covers one or at most a few of these only.

A *mapping* survey is an extensive reconnaissance survey with two stages: (*1*) summarizing on a map the available information from reports, *etc*; (*2*) planned treks to fill in gaps in the existing data, to check reliability of data, or to provide new data as suggested by the maps.

Area of competence—The physically optimum area for the survey as a whole. or for self-contained parts of it, or for different grades of field workers.

Traverse and transect—A line, on some definite plan, such as a compass bearing, across the area surveyed and from which observations are made. A series of parallel lines at equal intervals form a transect survey. A traverse may be curved and so form a regular but different pattern.

Pilot survey—A survey of a small sample of the farms, villages, *etc*, in the main survey. Serves to check the adequacy of the methods planned and of the efficiency of the organization.

Rapid or reconnaissance survey—A survey of a restricted nature designed to obtain a broad picture of the population in a short time. May (*a*) be directed towards obtaining the current position in a population whose characteristics are well known, or (*b*) be exploratory and aim to define the characteristics in order to plan a more comprehensive survey. The latter is sometimes called a ' preliminary reconnaissance '.

Route survey—Information confined to observations made during treks along existing roads, paths, rivers and railways. It may include complete farms contiguous to the route, a strip of definite width on one or both sides of the route, or consist of purely linear observation.

Linear survey—Recording confined to measurements along a line, whether a path or transect, of the presence and characteristics of crops, *etc*. This allows very rapid quantitative data to be obtained. The linear measurements must be converted into areas, trees per acre counts, *etc*, by calibration.

Concentric zones—An annulus or area between two concentric circles. A survey of village lands may be divided into zones, and enumeration be linear along footpaths radiating from the village centre, and linked by curved traverses forming arcs of the concentric circles (cobweb pattern).

Relay survey—Term used by Anyane to describe a systematic plan for the routes taken by a number of teams starting from the village centre and covering the radial paths and concentric arcs, without retracing routes already surveyed.

Gradient—The gradation in intensity or rate of change of a variable condition in terms of its distribution over a given area, *e.g.* proportion of food farms and plantations in successive concentric zones.

Financial accounting—Collection and analysis of records kept by the individual, *e.g.* farm ledgers, income and expenditure accounts, *etc*.

Cost accounting—The keeping of cost accounts specially designed as part of the survey, *e.g.* cost per acre data, or peasant family budgets.

Gate checks—Points on path, road or river at which people, animals, produce, *etc*, are enumerated.

Calibration—The translation of one set of observations into another set with which it is associated, linked or correlated, *e.g.* conversion of line survey data to area on a formula computed from a study of the pattern of distribution; the translation of eye estimates into a series suitable for statistical analysis, by physical check of a fraction of the eye estimates; cultivated area computed from production data using yield per acre data obtained from a sub-sample only of the total farms surveyed; annual food supply

and consumption computed from gate check data obtained on a few days or periods distributed over the season.

Linked pairs—Factors positively or negatively correlated, *e.g.* inadequate food supply being the determinant of low nutritional status producing certain deficiency disease symptoms, which can be readily recognized. The incidence of disease may be recorded over several seasons or areas, and used as the indicator of food supply, the correlation between the two factors having been observed in a previous season.

Automatic checks—The recording of two factors, which are known to be correlated, *e.g.* leaf colour and general health, or weed growth and canopy in a plantation. These built-in checks immediately show up impossible combinations.

Organizational charts—A diagram showing the organization of the survey, with panels indicating the authority and functions of each individual or class of worker.

Flow sheets—A list or chart showing precisely what happens to each record received in headquarters or district survey office. The test of efficiency of a set of flow sheets is whether they would allow a person conversant with survey methods and procedure to take the original data received, and carry them through all stages to final report summary stage without further assistance.

Wall charts—Graphs, diagrams, diagrammatic maps, *etc*, showing the current stage of the survey and simple summary data of a size large enough to be intelligible to any one sitting at the office desk.

(*Received January 1956*)

REFERENCES

[1] A Questionnaire for the Study of Native Economies (1942), *Farm and Forest*, **3**, No. 3, Nigeria
[2] Essentials of Rural Welfare (1949), *Food Agric. Orgn U.N.O.*, March
[3] Analysis of Field Enquiries into Living Conditions of Selected Social Groups. (1948) Miscellanies. *U.N. Dept. of Social Affairs*
[4] Young, P. V. (1950). *Scientific Social Surveys and Research*, 2nd edn.
[5] Paston, M. (1950). *Surveys, Polls and Samples.*
[6] Yates, F. (1949). *Sampling Methods for Census and Surveys*
[7] Hunt, K. E. (1952). *Statistics for Colonial Agriculture*

Response of Rice to Certain Fertilizers in Zanzibar

G. E. Tidbury
Department of Agriculture, Zanzibar

The fertilizer status of the more important soils of the Zanzibar Protectorate has been investigated for a number of years and the work was greatly extended in 1947 when it was found that sodaphosphate produced in Kenya, applied before planting, caused noteworthy increases in the yield of maize. These investigations and the classification of the Protectorate's soils were undertaken concurrently[1–5]. It was found that soils derived *in situ* from limestones had adequate reserves of phosphates but needed potash and nitrogen, while soils derived from re-sorted second-hand mainland deposits had little need of potash but were very deficient in phosphate and also needed nitrogen.

Rice cannot be grown with success on all the soils of the Protectorate, the principal rice soils being as follows:

Zanzibar Island

(*i*) The *changa* soils which are sandy soils on non-calcareous sediments: some are relatively infertile and all exhibit a pronounced need for phosphates.

(*ii*) The *namo* soils which are sticky and heavy clay soils, often quite fertile and suitable for rice but needing phosphates.

Pemba Island

(*i*) The *mtifutifu* soils which are sandy, infertile and in need of phosphates.

(*ii*) The *kinyefu* soils which are found in restricted valleys: their nutrient status is still not clear.

(*iii*) The *kinako* soils, which are very heavy, cracking clays with limestone parent material. Their nutrient status still needs investigation but their seasonal physical changes probably affect fertilizer responses.

Most rice is grown on the first three soil types mentioned above and, since it responds to phosphatic and nitrogenous fertilizers on all three, rice growers have been generally advised to apply superphosphate when the seed is sown, and sulphate of ammonia as soon as the main rains stimulate the crop into rapid growth. The dressings recommended were 2 cwt/acre of single superphosphate and 1 cwt/acre of sulphate of ammonia. These quantities were conservative and safely within the range for providing economic monetary returns.

Several rice experiments have now been completed, and it is possible to subject the results to critical examination and to make useful comparisons between them. If the early exploratory experiments, in which fertilizers were applied at a single level, the experiments on *kinyefu* and *kinako* soils which cannot be brought into a general picture of nitrogen and phosphate

status, and two experiments laid down under abnormal weather conditions are omitted, results are available from 15 full scale field experiments. Of these, 10 were designed as 4^2 factorial experiments, with four levels of each fertilizer, and five were 3^2 factorial experiments with three levels of each fertilizer. As earlier trials had shown conclusively that rice does not respond to potash on these soils, no potash treatments were included.

COMPONENTS OF THE RESPONSE TO A FERTILIZER TREATMENT

It may be of value briefly to consider the response of a crop to various levels of a fertilizer and how yield curves can be analysed by the breakdown of the response into its component parts. Details of the appropriate statistical analyses have been published by F. YATES[6].

The simpler of the two designs used included three levels of phosphate, one of which was nil, that is to say P_0, P_1 and P_2. The variance due to these three levels has two degrees of freedom (or independent comparisons), one representing the 'linear' component, *i.e.* the direct response to the greater level of fertilizer, and the other the 'curvature' component which denotes the difference in the steepness of the slopes of the lower and upper portions of the curve. The linear component is the simple comparison A_2-A_0 (when the three levels of fertilizer A are A_0, A_1 and A_2) and the curvature is the comparison $A_2+A_0-2A_1$. A marked positive curvature is obtained therefore when A_1 is comparatively small and the curve bends upward indicating a greater response to the higher level of fertilizer. A negative curvature represents the reverse, that is when the response to the higher level is proportionately less than to the lower. In this case the curve above A_1 becomes less steep and the law of diminishing returns is manifest.

In three-level factorial experiments it is customary to denote the linear component of the response to fertilizer A as A' and the curvature by A''. As however A' and A'' are also used in four-level experiments and have a rather different meaning, it is proposed in this paper to denote linear and curvature as $A(l)$ and $A(c)$ respectively.

When four levels of fertilizer are applied, of which the lowest may be nil, the response curve is more complex. The four yields provide three independent comparisons representing three degrees of freedom:

$$A' = A_3+A_2-A_1-A_0$$
$$A'' = A_3+A_0-A_2-A_1$$
$$A''' = A_3+A_1-A_2-A_0$$

A statistically significant response to A' is therefore to be expected under the following circumstances: (*i*) when the yield of the A_0 plots is low and that of A_1 also low or medium, compared with the yields of the A_2 and A_3 plots, either or both of which yield heavily, or (*ii*) if A_3 is not particularly high, when the A_2 yield is very high.

Thus a significant A' indicates generally a large response to the higher levels of fertilizer and that heavier dressings than A_1 are worth applying. When A_1 and A_3 yields are not greatly dissimilar, as is frequently the case, the response A' roughly corresponds to the linear component of a three point response curve.

Secondly, a significant response to A'' will be found when the yield from A_3 is particularly high or when the responses to the medium dressings are

low in comparison. This may indicate that unless heavy applications are made, the fertilizer is not likely to be effective.

Thirdly, a significant response A''' may be expected: (*i*) when A_1 causes a large yield increase, since it is unlikely that A_3 will be high if A_2 is low, or (*ii*) if the A_3 yield falls away, when the A_1 yield is much greater than A_2.

Thus A''' could under some circumstances be the converse of A' for, if A_3 is more or less equal to A_0, $A'=A_2-A_1$ and $A'''=A_1-A_2$.

Sometimes more than one component may be found to be statistically significant: this is true for phosphate in several of the experiments described below. This will occur when the response curve is steep and straight with rather disproportionately high yields at the A_3 level.

The agricultural implications of these components become easier to understand when the yield at certain levels is low, thus: (*i*) if A_0 is low, as it may well be, a significant A'' indicates a large response to A_3; (*ii*) if A_1 is low, a significant response to A''' indicates a very large response to A_3; (*iii*) if A_2 is low, a significant response to A' indicates a very large response to A_3; but (*iv*) if A_3 is low, a significant A' indicates high response to A_2 and a significant A''' indicates a high response to A_1.

In short, A' is largely the measure of the response to A_2 and partly to A_3; A'' is largely the measure of the response to A_3 and partly to A_2; while A''' is largely the measure of the response to A_1.

INTERACTIONS

When two or more fertilizers are applied to a crop in a factorial experiment, each may occasion the responses described above and these responses represent the average effect of the individual fertilizer at all levels of the others present. But beyond these responses to individual fertilizers, there may be occasioned other responses—which may be positive or negative, *i.e.* which may increase or decrease yield—due to interactions between the fertilizers. Thus if both nitrogen and phosphate are applied, the net increase in yield may be greater than the sum of the responses to nitrogen and phosphate when each is applied alone. This extra yield is due to a positive interaction between the two fertilizers.

If two fertilizers, A and B, are each applied at three levels, the variance due to interaction will admit four independent comparisons and these represent the four components of the interaction, namely,

(*a*) linear $A \times$ linear B,

(*b*) curvature $A \times$ curvature B,

(*c*) linear $A \times$ curvature B,

(*d*) curvature $A \times$ linear B.

Thus a significant positive response to the component (*c*) above would indicate that positive curvature in the B response, *i.e.* disproportionately high yields for the B_2 dressings, is enhanced at the higher level of A compared with the lower.

When four levels each of A and B are applied, there are nine components of the interaction. Some of these are of less obvious agricultural importance than others (and were partially confounded in the 4^2 design used in these experiments) but those which achieved statistical significance will be discussed

below. The precise agricultural implications of some of these components of interaction are, however, sometimes difficult to comprehend.

EXPERIMENTAL RESULTS

Response to sulphate of ammonia

In *Table 1* the order is determined by the yields of the N_0P_0 plots and is thus a rough measure of the initial fertility of the land.

The treatment N_1 is 1 cwt/acre sulphate of ammonia, and N_2 and N_3 are respectively double and treble this dressing.

Table 1. Response to sulphate of ammonia

Year	*Place*	*Soil type*	*Yields of paddy, lb./acre*				*Significant responses*	
			N_0	N_1	N_2	N_3	*In* 4^2 *expts*	*In* 3^2 *expts*
1950	*Kisongoni*	changa	1527	1642	1886	1622	—	
1951	*Kibonde Mzungu* (a)	changa *derived*	1664	1840	2056	—	—	N(*1*)
1950	*Mahonda*	changa	1771	1685	1936	1776		
1951	*Kizimbani*	changa	1375	1504	1629	—		N(*1*)
1950	*Cheju*	namo	1004	1323	1546	1659	N′, N‴	
1951	*Kibonde Mzungu* (b)	changa *derived*	1067	1227	1373	—		N(*1*)
1949	*Cheju*	namo	1240	1610	2240	2280	N′	
1949	*Kisongoni*	changa	1070	1250	1640	1320	N′	
1951	*Konde*	mtifutifu	733	1296	1411	—	—	N(*1*), N(*c*)
1951	*Cheju*	namo	371	594	769	—		N(*1*)
1949	*Mahonda*	changa	450	650	890	850	N′	
1950	*Msuka*	mtifutifu	884	1362	1683	1465	—	
1954	*Konde*	mtifutifu	413	565	588	509	—	
1954	*Kiungoni*	mtifutifu	394	613	706	862	N′	
1954	*Wapape*	mtifutifu	373	512	629	706	N′	

The above results may be roughly divided into three groups according to fertility, giving the average responses to the three levels of application shown in *Table 2*.

Table 2

		N_1	N_2	N_3
High fertility areas	*Response, lb./acre*	131	338	252
	Percentage yield increase over control	9	23	17
Medium fertility areas	*Response, lb./acre*	299	590	645
	Percentage yield increase over control	33	66	72
Low fertility areas	*Response, lb./acre*	238	396	376
	Percentage yield increase over control	47	79	75

It is clear that the percentage increases in yield caused by dressings of sulphate of ammonia are highest in areas of low fertility and lowest in the most fertile areas. The actual yield increases, in lb./acre, on the other hand,

are less dissimilar. *Figure 1* shows the actual increases and indicates the yield levels above which the value of the extra rice exceeds the cost of the fertilizer.

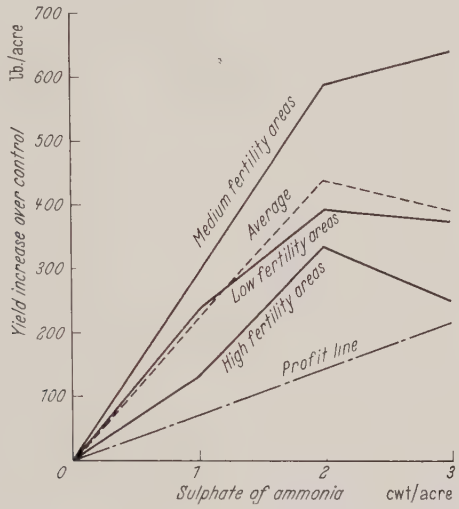


Figure 1. General response to sulphate of ammonia

It will be seen that the response up to the 2 cwt/acre level is purely linear; the response to the second cwt of fertilizer is as great as the response to the first. This is also clearly shown in the statistical analyses in which N′ and N(*1*) are so frequently the only significant component.

Above N_2 the response declines and the profit decreases. The absence of response to N″ in the 4_2 experiments is also evidence of this. Dressings greater than 2 cwt/acre of sulphate of ammonia cannot be recommended.

Response to superphosphate

In these experiments, dressings of superphosphate were applied at different sets of three levels. For this reason the average responses at individual levels are based on fewer results and are thus less acceptable. On the other hand a continued response at higher levels can be observed.

Table 3 shows the response to superphosphate. The dressing P_1 equals 1 cwt/acre of single superphosphate and P_2, P_3, *etc*, are multiples of this amount.

The average responses, divided into three fertility levels, are given in *Table 4*.

The response to superphosphate is markedly different from the response to sulphate of ammonia. Percentage increases due to phosphate are as much as four times as great as for nitrogen and actual yield increases are about twice as great. As with the nitrogen response, the percentage increases are largest at low fertility levels and lowest in the more fertile plots. But, unlike the response to nitrogen, the actual weight increases also follow this pattern. The most striking difference from the nitrogen picture, however, is that there is no great diminution in response above the 2 cwt/acre level. Yields from P_3 and P_4 are well above the P_2 yields. Dressings of 6 cwt/acre cause still further yield increases in the high fertility plots and there is no

decrease of yield in the medium fertility areas. Unfortunately the results of high level applications in infertile areas are too few to provide a useful average although the single experiment of this sort showed higher yields at P_6 than at P_2 and P_4. On the other hand, less financial profit accrues to the higher dressings.

Table 3. Response to superphosphate

Year	*Place*	*Soil type*	*Yields of paddy lb./acre*						*Significant responses*	
			P_0	P_1	P_2	P_3	P_4	P_6	*In* 4^2 *expts*	*In* 3^2 *expts*
1950	*Kisongoni*	changa	1674		1651		1621	1731	—	
1951	*Kibonde*	changa								
	Mzungu (a)	*derived*	1771		1936					P
1950	*Mahonda*	changa	1100		1805		1948	2315	P′, P′′′	
1951	*Kizimbani*	changa	1271	1529	1708					P(*1*)
1950	*Cheju*	namo	1069		1386		1512	1565	P′, P′′′	
1951	*Kibonde*	changa								
	Mzungu (b)	*derived*	1087	1267	1313					P(*1*)
1949	*Cheju*	namo	1160		2030		2100	2080	P′, P′′, P′′′	
1949	*Kisongoni*	changa	970		1200		1540	1570	P′	
1951	*Konde*	mtifutifu	605	1321	1515					P(*1*), P(*c*)
1951	*Cheju*	namo	595	564	576					—
1949	*Mahonda*	changa	480		760		710	890	P′, P′′′	
1950	*Msuka*	mtifutifu	308	1509	1726	1851			P′, P′′, P′′′	
1954	*Konde*	mtifutifu	183	533	702	655			P′, P′′, P′′′	
1954	*Kiungoni*	mtifutifu	300	450	913	913			P′	
1954	*Wapape*	mtifutifu	12	507	900	800			P′, P′′, P′′′	

Table 4

	P_1	P_2	P_3	P_4	P_6
High fertility areas, response, lb./acre ..	258	320	366*	413	589
Percentage yield increase over control ..	19	23	27*	30	43
Medium fertility areas, response, lb./acre ..	288	443	599*	755	760
Percentage yield increase over control ..	33	50	68*	86	86
Low fertility areas, response, lb./acre ..	549	744	854	†	†
Percentage yield increase over control ..	214	289	332	†	†

* = by interpolation.
† = insufficient results.

The averages for actual yield increases are shown in *Figure 2*.

The significant components of the phosphorus response which emerge from the analyses of variance also clarify the nature of the response. In the 3^2 experiments P(*1*) was usually significant but P(*c*) only once. In the 4^2 experiments P′, P′′ and P′′′ are all significant in four experiments, P′, P′′′ in three experiments and P′ alone in two. This indicates that the response to the higher levels of fertilizer is large with little or no manifestation of the law of diminishing returns within the limits of the experimental treatments. Furthermore the responses to the lowest level are often also very great, since P′′′ is so frequently significant, the curve rising steeply from the start. And since P′′ is also commonly significant, there is a tendency to a disproportionate increase due to the highest level in the experiments.

Table 5. Statistically significant interactions between nitrogen and phosphorus

Year	*Place*	*Soil type*	*Significant interactions*											
			4^2 *Experiments*								3^2 *Experiments*			
			N′P′	N′P″	N′P‴	N″P′	N″P″	N‴P′	N‴P″	N‴P‴	N(*1*)P(*1*)	N(*1*)P(*c*)	N(*c*)P(*1*)	N(*c*)P(*c*)
High Fertility Areas														
1950	*Kisongoni*	changa												
1951	*Kibonde Mzungu (a)*	changa *derived*										*		
1950	*Mahonda*	changa								*				
1951	*Kizimbani*	changa												
1950	*Cheju*	namo		*										
Medium Fertility Areas														
1951	*Kibonde Mzungu (b)*	changa *derived*												
1949	*Cheju*	namo		*										
1949	*Kisongoni*	changa				*				*				
1951	*Konde*	mtifutifu									**	*		
1951	*Cheju*	namo												*
Low Fertility Areas														
1949	*Mahonda*	changa	*											
1950	*Msuka*	mtifutifu												
1954	*Konde*	mtifutifu	*											
1954	*Kiungoni*	mtifutifu		*		*								
1954	*Wapape*	mtifutifu	*											

** = P at 0·01.
* = P at 0·05.

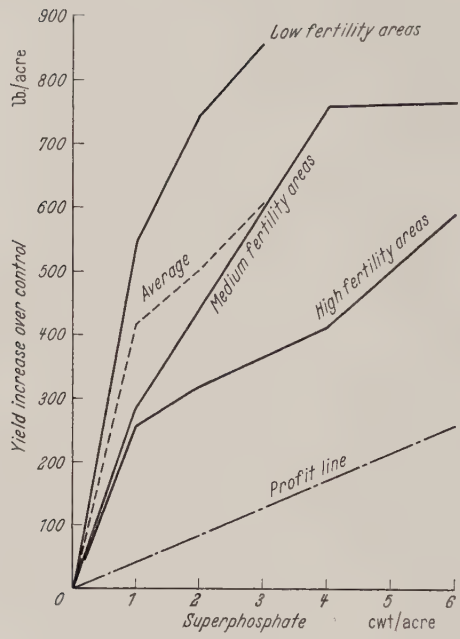


Figure 2. General response to superphosphate

Interaction

The interactions between nitrogen and phosphate which proved to be statistically significant are shown in *Table 5*.

In the 10 4^2 experiments the following components of interaction were significant: N′P′ thrice, N′P″ thrice, N″P′ twice, N‴P‴ twice.

The other five components never attained statistical significance, so the nature of the interaction between nitrogenous and phosphatic fertilizers must be sought among the four significant components.

Since A' is largely the measure of the response to the A_3 and A_2 levels, the component N′P′ clearly indicates that the highest levels of each fertilizer cause enhanced and disproportionately high yields at high levels of the other (see *Table 6*).

Table 6. Response lb./acre Mahonda 1949

	N_0	N_3
P_0	360	560
P_3	520	1240

Table 7. Response lb./acre Konde 1951

	N_0	N_2
P_0	618	598
P_2	864	1922

The response to N_3 alone was $560-360=200$ lb./acre and that to P_3 alone was $520-360=160$ lb./acre. But the response to N_3P_3 is more than $200+160=360$ lb./acre, it is actually 880 lb./acre, that is an extra 520 lb./acre was obtained due to the positive interaction between nitrogen and phosphorus at high levels. This is a frequently observed phenomenon on many of the Protectorate's soils and was also shown in one of the 3^2 experiments (see *Table 7*).

The value of this positive interaction in terms of enhanced yield must be taken into account when assessing the economic return from either fertilizer. Even if the response to nitrogen alone is not great it may still be well worth applying nitrogen for the sake of the interaction with phosphate (see *Table 8*).

Table 8. Response lb./acre
Konde 1954

	N_0	N_2
P_0	245	25
P_2	513	913

Table 9. Response lb./acre
Wapape 1954

	N_0	N_2
P_0	15	15
P_1	313	388
P_2	725	1063

This effect was even more pronounced at Wapape in 1954 where the response to nitrogen was observed only when phosphate was present in sufficient quantity (see *Table 9*).

It is of interest to observe that significant N′P′ interactions in the 4^2 experiments were only obtained in the experiments conducted in areas of low fertility. This may, perhaps, be fortuitous.

The second most common significant component of interaction amongst the 4^2 experiments was N′P″. This occurred thrice; accompanied in one case by the masking effect of a significant N″P′ component. This component represents the expression:—

$$(N_3+N_2-N_1-N_0)\times(P_3+P_0-P_2-P_1)$$

The responses to phosphate at separate levels of nitrogen in two experiments at Cheju, shown in *Figures 3* and *4*, illustrate this. There is some similarity between the two diagrams and the chief characteristic is that P_2 and P_1 yields are very low when nitrogen is either absent or present only at the N_1 level. That is to say, the magnitude of the component $P_3+P_0-P_2-P_1$ is greatest at the N_1 and N_0 levels of nitrogen and, if N_1 and N_0 are small, then N′ $(=N_3+N_2-N_1-N_0)$ is clearly at its greatest. In agricultural terms, high nitrogen dressings are needed if maximum responses are to be obtained from medium and low phosphate dressings. The reverse is also true: medium levels of phosphate must be present to obtain the best response to high levels of nitrogen.

The reverse of the above component of interaction was observed twice when N″P′ proved significant. A good example was at Kiungoni in 1954 and the response curves for nitrogen at separate levels of phosphate are shown in *Figure 5*. Here the yields of N_1 and N_2 are low unless P_3 and P_2 levels of phosphate are present, *i.e.* the reverse of the component N′P″ discussed above.

The only other component of interaction to be significant in the 4^2 experiments was N‴P‴, *i.e.* the interaction between the expressions:

$$(N_3+N_1-N_2-N_0)\times(P_3+P_1-P_2-P_0)$$

This was clearly shown at Mahonda in 1950 where the yields for N_1 and N_3 were low at the P_2 and P_0 levels of phosphate and conversely P_1 and P_3

yields were high where N_1 and N_3 levels of nitrogen were present (see *Figure 6*).

Since A''' is largely a measure of the response to A_1, this component of interaction indicates that the response to a low level of either nitrogen or phosphate is enhanced when at least a low level of the other is present.

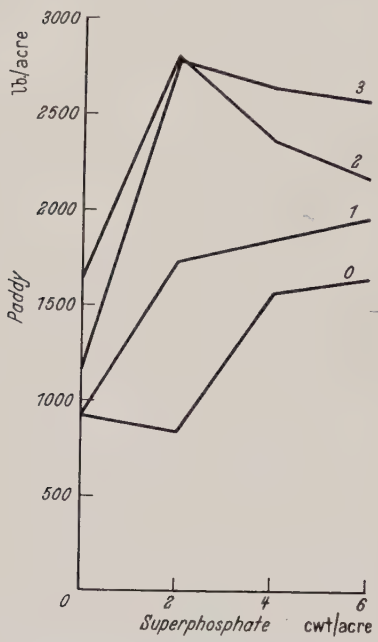


Figure 3. Response to phosphate (N′P″ *component of interaction*) *Cheju 1949, when 3, 2 and 1 cwt/acre and no sulphate of ammonia was present*

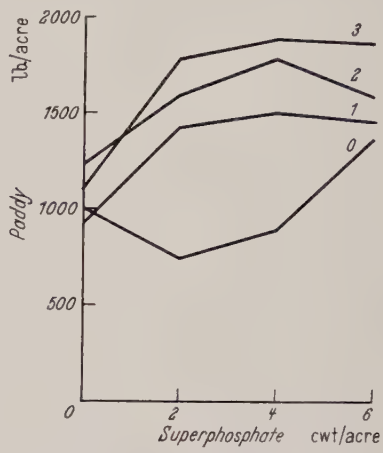


Figure 4. Response to phosphate (N′P″ *component of interaction*) *Cheju 1950, when 3, 2 and 1 cwt/acre and no sulphate of ammonia was present*

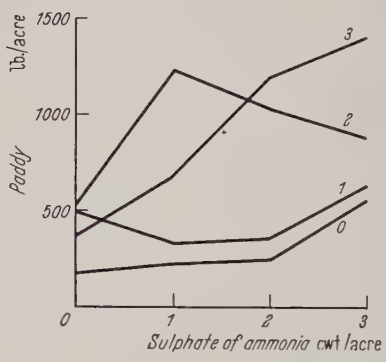


Figure 5. Response to nitrogen (N″P′ *component of interaction*) *when 3, 2 and 1 cwt/acre and no superphosphate was present*

In the 3^2 experiments, the N(*1*)P(*1*) component has already been discussed. Beyond this, N(*1*)P(*c*) occurs significantly twice and N(*c*)P(*1*) once. At Kibonde Mzungu in 1951 the component N(*1*)P(*c*) is clearly shown by a low yield for P_1 in the absence of nitrogen, *i.e.* the low P_1 contributes to the linear response N(*1*) ($=N_2-N_0$) (see *Table 10*).

The remaining component N(*c*)P(*c*) was significant at Cheju in 1951. Here the yield for P_1 was low at the N_1 level of nitrogenous fertilizer and similarly N_1 yield was low at the P_1 level. In other words the expressions for curvature $A_2+A_0-2A_1$ are mutually dependent and this largely conforms

to the interdependance of yields at the low levels of each fertilizer shown in the 4^2 experiments by the significant component N'''P''' (see *Table 11*).

Most productive interaction

The actual value of the interaction, apart from main effects, for every combination of fertilizers used in these experiments can be ascertained by adding the yield of the appropriate plot to the N_0P_0 yield and subtracting the N alone and P alone yields at the same levels.

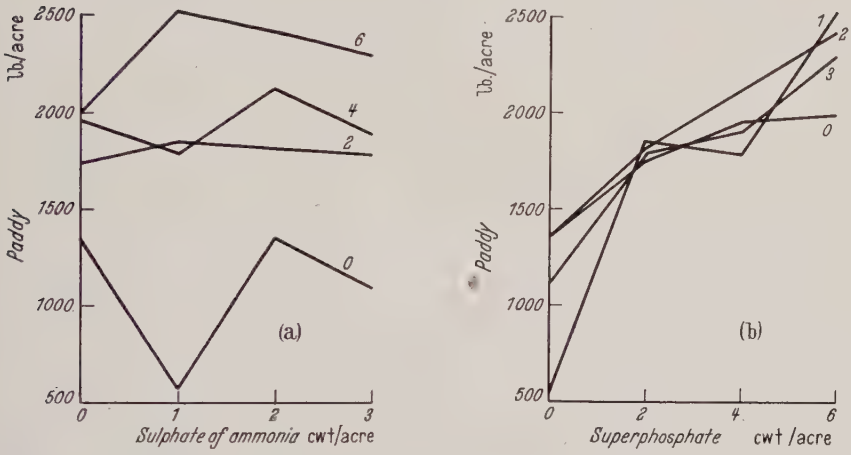


Figure 6. Response to nitrogen and phosphate (N'''P''' *component of interaction*) *Mahonda 1950:* a *when 6, 4 and 2 cwt/acre and no superphosphate was present;* b *when 3, 2 and 1 cwt/acre and no sulphate of ammonia was present*

Table 12 shows these values as averages for every combination of fertilizers for the three categories of soil fertility. In this table the figures in the expressions N_3P_4, *etc*, represent cwt per acre.

These averages are, in most cases, based on too few experiments to be taken as more than a rough indication. The averages of all experiments regardless of fertility level are given in *Table 13*.

Table 10. Yield, lb./acre

	N_0	N_1	N_2
P_0	1000	1040	1220
P_1	1000	1260	1540
P_2	1200	1380	1360

Table 11. Yield, lb./acre

	N_0	N_1	N_2
P_0	402	716	666
P_1	346	460	886
P_2	366	606	756

From *Table 13* it can be seen that the N_3P_3 dressing involves the most productive interaction between nitrogen and phosphate, followed by N_2P_3 and N_3P_2.

Most profitable dressing

The choice of the most profitable dressing, however, must depend not only on the total response to fertilizers plus the interaction, but also on the cost of the fertilizers and the value of the extra rice. Using the (1955) landed costs of fertilizers and the approximate local price of paddy, the averages given in *Table 14* were obtained.

Table 12. Responses to interactions lb./acre

Fertility	N_1P_1	N_1P_2	N_1P_3	N_1P_4	N_1P_6
High	−374	451	—	163	467
Medium ..	285	580	—	−120	180
Low	338	80	141	120	200
Fertility	N_2P_1	N_2P_2	N_2P_3	N_2P_4	N_2P_6
High	213	369	—	80	193
Medium ..	537	389	—	−340	−280
Low	541	453	727	160	280
Fertility	N_3P_1	N_3P_2	N_3P_3	N_3P_4	N_3P_6
High	—	793	—	441	508
Medium ..	—	1160	—	600	660
Low	205	518	816	320	520

Table 14d indicates very clearly that the most profitable combination is 2 cwt/acre of sulphate of ammonia plus 3 cwt/acre of superphosphate. *Table 14a, b* and *c* however, indicate that in areas of high fertility there is less likelihood of much financial profit accruing from the use of fertilizers, certainly not at the higher levels. Their use is clearly most profitable in areas of medium fertility, while in areas of low fertility the higher levels of phosphate may not repay application.

CONCLUSIONS

On the *changa*, *namo* and *mtifutifu* soils of the Zanzibar Protectorate the response of rice to nitrogen in the form of sulphate of ammonia is approximately linear up to the 2 cwt/acre level where a yield increase of 600 lb./acre of paddy can be obtained in the presence of phosphate. Yield responses to higher dressings decline and are much less profitable.

Useful applications of single superphosphate in the presence of nitrogen can apparently be made at much higher levels and occasion greater increases

Table 13. Average values of response to interaction, lb./acre

	N_1	N_2	N_3
P_1	229	499	205
P_2	505	403	729
P_3	141	727	816
P_4	78	−47	474
P_6	327	50	561

Table 14. Profit from most profitable dressings, shillings/acre

(*a*) *High fertility areas*

	N_1	N_2	N_3
P_1	43	152	—
P_2	76	119	24
P_3	—	—	—
P_4	−82	−15	11
P_6	−47	26	−19

(*b*) *Medium fertility areas*

	N_1	N_2	N_3
P_1	97	170	—
P_2	180	209	268
P_3	—	—	—
P_4	122	297	318
P_6	158	253	275

(*c*) *Low fertility areas*

	N_1	N_2	N_3
P_1	193	145	97
P_2	201	233	219
P_3	182	341	251
P_4	−18	63	65
P_6	5	100	132

(*d*) *All areas*

	N_1	N_2	N_3
P_1	146	155	97
P_2	152	167	171
P_3	182	341	251
P_4	−4	102	122
P_6	30	114	103

than sulphate of ammonia. Dressings as great as 4 cwt/acre are apparently profitable and possibly higher levels still may be worth while.

A study of the interaction between nitrogen and phosphate indicates that its main features are: (*i*) the responses to the higher levels of each fertilizer are enhanced when the other fertilizer is also present at a high level; (*ii*) a high level of nitrogen is needed if maximum response is to be had from medium and low levels of phosphate and *vice versa*; (*iii*) the response to a low level of either nitrogen or phosphate is enhanced when at least a low level of the other fertilizer is present.

The actual response to the interaction in terms of extra paddy per acre is greatest when 3 cwt/acre each of sulphate of ammonia and superphosphate are applied, but the positive response to the nitrogen–phosphate interaction is remarkably high at most combinations and levels of manuring used in these experiments.

When the value of the extra rice and the cost of the fertilizers is considered, however, the most profitable dressing is 2 cwt/acre of sulphate of ammonia plus 3 cwt/acre of superphosphate. The greatest profits from fertilizers can be obtained on soils of medium and low fertility. Heavy dressings are less likely to be profitable especially where initial fertility is high.

ACKNOWLEDGEMENTS

My thanks are due to Mr A. K. Briant, Director of Agriculture, for his close interest in these experiments and his valuable comments on the results. I must also gratefully acknowledge the work of those other officers of the Department of Agriculture who assisted in the planting and harvesting of certain of these experiments. The analyses of the 4^2 experiments were undertaken with the helpful advice of Mr P. Robinson, previously statistician in the E.A.A.F.R.O.

(*Received November 1955*)

REFERENCES

[1] CALTON, W. E. (1949). A Reconnaissance of the Soils of Zanzibar Protectorate, *Tech. Commun. Bur. Soil Sci., Harpenden No. 46*

[2] TIDBURY, G. E. and CALTON, W. E. (1950). The Use of Micro-plots in a Reconnaissance Survey of the Nutrient Status of the Soils of Zanzibar Island, *E. Afr. Agric. J.*, **15,** 108

[3] TIDBURY, G. E. (1954). Crop Responses to Fertilizers and Manures in Zanzibar, *Proc. 2nd Inter-African Soils Conf. Léopoldville*, 761

[4] CALTON, W. E., TIDBURY, G. E. and WALKER, G. F. (1955). A Study of the More Important Soils of Zanzibar Protectorate, *E. Afr. Agric. J.*, **21,** 53

[5] *Ann. Rep., Zanz. Dept Agric.*, 1949, *Suppt. to Ann. Rep.*, 1950, 1951, 1952, 1953, 1954

[6] YATES, F. (1937). The Design and Analysis of Factorial Experiments, *Tech. Commun. Bur. Soil Sci., Harpenden No. 35*

The Application of Foliar Analysis to Oil Palm Cultivation: I. Sampling Technique

H. Broeshart
Research Department, Huilever S.A., Belgian Congo

Between March, 1953, and March, 1954, a series of samples from young and mature oil palms (*Elaeis Guineensis* Jacq.) was taken with the object of endeavouring to establish the influence on the chemical composition of the leaves of the following factors: (*i*) morphological position of the leaves; (*ii*) age of the palms; (*iii*) climatological conditions; (*iv*) sampling errors.

The determination of the influence of the age of palms on the chemical composition of the leaves is not a simple procedure as, under plantation conditions, differences in planting technique, cultural methods, origin of seed and varying soil conditions may not be eliminated. Only in cases, where replacements have been made in a block, may the differences in chemical composition of the leaves be ascribed to differences in age, the other factors mentioned above being constant, provided there is no shading effect of the older on the younger palms.

EXPERIMENTAL PROCEDURE

In a plantation in the Central Congo Basin (Yaligimba), an experimental area was chosen in a block, containing palms in the productive stage but also a considerable number of replacements, still in the vegetative stage of development. Twenty young and twenty old palms in reasonable proximity to each other were selected at random and sampled at monthly intervals. The leaflets from the centre of the first and ninth leaves were taken as being representative and sampled in the mornings between 7 and 10 a.m. All samples were individually analysed (80 samples per month).

The experiment may be considered as a split plot, comprising three errors. The estimation of the error variance for age of the palms is based on only 40 palms, as the successive monthly samplings may not be considered as randomized replications. Further, the error variance of the influence of the morphological position of the leaf on its chemical composition may, for the same reason, be based only on 40 palms. As the first and ninth leaves of the same palms have been sampled, the error variance for ' age ' is not the same as the error variance for ' leaf '. For the calculation of the error variance for sampling time and its interactions with ' age ' and ' leaf ', all data accumulated during the year (960) may be used.

DISCUSSION

Tables 1 and *2* give the analytical data obtained during the period of one year as a mean of 20 palms. *Table 3* shows the analysis of variance. In

Table 1. Foliar analysis of individually, monthly sampled palms (average of 20 palms) (data expressed as per cent of dry matter)

Sampling time	% Potassium				% Phosphorus				% Calcium				% Magnesium			
	Leaf 1		Leaf 9		Leaf 1		Leaf 9		Leaf 1		Leaf 9		Leaf 1		Leaf 9	
	Young	Old	Young	Old	Young	Old	Young	Old	Young	Old	Young	Old	Young	Old	Young	Old
1953																
March	1·85	2·06	1·34	1·34	0·147	0·198	0·126	0·163	0·564	0·612	0·742	0·709	0·264	0·380	0·252	0·408
April	2·05	1·88	1·39	1·04	0·195	0·206	0·165	0·175	0·615	0·667	0·802	0·770	0·384	0·405	0·323	0·429
May	1·80	1·70	1·15	1·38	0·185	0·204	0·169	0·170	0·615	0·666	0·725	0·677	0·267	0·357	0·249	0·356
June	1·75	2·00	1·42	1·59	0·189	0·201	0·155	0·190	0·606	0·598	0·644	0·639	0·296	0·370	0·299	0·344
July	1·91	1·72	1·76	1·34	0·209	0·168	0·196	0·161	0·591	0·607	0·601	0·667	0·402	0·414	0·388	0·491
Aug.	1·65	1·78	1·44	1·28	0·206	0·200	0·183	0·188	0·593	0·597	0·751	0·626	0·359	0·398	0·343	0·380
Sept.	1·54	1·90	1·29	1·44	0·210	0·202	0·207	0·190	0·621	0·624	0·612	0·698	0·273	0·325	0·274	0·382
Oct.	1·80	1·42	1·35	2·00	0·215	0·202	0·204	0·221	0·590	0·663	0·649	0·753	0·276	0·338	0·253	0·358
Nov.	1·74	1·57	1·22	1·22	0·223	0·236	0·220	0·219	0·616	0·603	0·691	0·739	0·286	0·338	0·286	0·353
Dec.	1·68	1·82	1·17	1·43	0·211	0·218	0·194	0·198	0·595	0·593	0·728	0·716	0·399	0·298	0·377	0·315
1954																
Jan.	2·04	2·15	1·63	1·82	0·189	0·213	0·179	0·171	0·520	0·534	0·705	0·607	0·283	0·326	0·298	0·322
Feb.	2·05	1·84	1·68	1·36	0·170	0·196	0·157	0·165	0·582	0·531	0·704	0·712	0·241	0·275	0·280	0·319

addition, *Figures 1* and *2* have been prepared to facilitate the comparison of the changes in leaf composition with changes in rainfall and insolation (*Figure 3*).

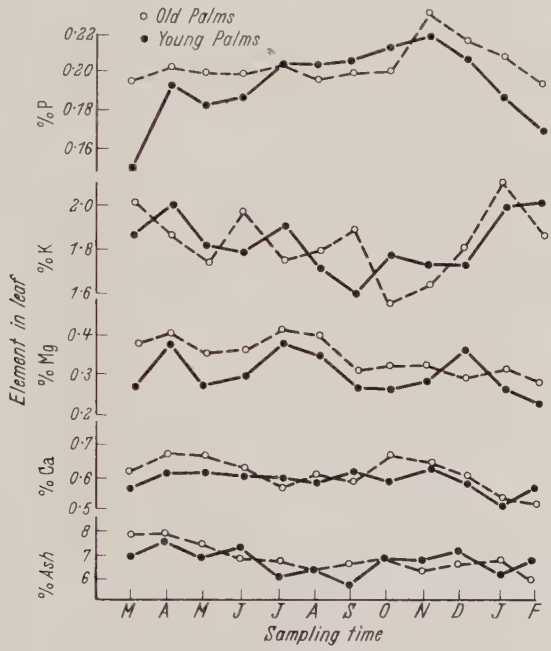


Figure 1. Influence of sampling time on the chemical composition of the first leaf

Morphological position of the leaves—The differences in the chemical composition of the first and ninth leaves appear to be highly significant in respect of the potassium, phosphorus, calcium and the ash content (as percentage

Table 2. Foliar analysis of individually, monthly sampled palms (average of 20 palms). Ash as per cent of dry matter

Sampling time	Leaf 1		Leaf 9	
	Young	Old	Young	Old
1953				
March	7·20	7·90	7·31	7·20
April	7·99	8·18	7·84	6·69
May	7·29	8·77	6·55	7·75
June	7·66	7·21	6·62	6·84
July	6·01	6·86	5·42	6·10
Aug.	6·49	6·44	6·09	6·24
Sept.	5·46	6·60	5·06	6·05
Oct.	7·00	7·29	7·04	6·81
Nov.	6·97	6·52	6·54	6·28
Dec.	7·40	6·86	6·47	6·82
1954				
Jan.	6·51	6·95	7·00	6·40
Feb.	7·03	6·02	7·08	6·61

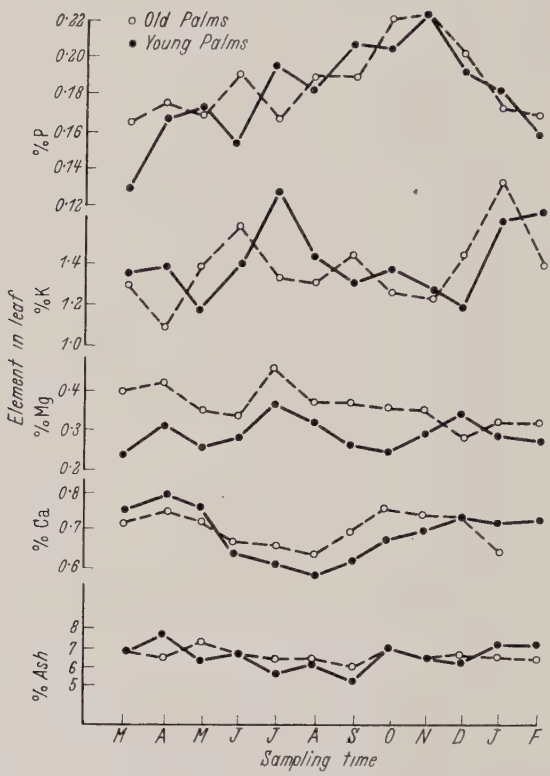


Figure 2. Influence of sampling time on the chemical composition of the ninth leaf

of dry matter). The difference in magnesium content just attains significance at P=0·05. The interaction, leaf × age is only significant for the magnesium content of the samples; this would seem to suggest that the change in magnesium content, as a function of the physiological age of the leaves, is not the same for young and old palms. The interaction, leaf × sampling time is highly significant for the potassium and calcium content of the leaves. It may be seen from *Table 1* and from *Figures 1* and *2* that the fluctuations of potassium and calcium are greater in the ninth than in the first leaf as a consequence of the change from the dry to the wet season.

Age of the palms—The only apparent difference in chemical composition is in the magnesium and ash content, both of which are higher for the old palms. The interaction age × sampling time is highly significant for potassium, phosphorus, magnesium and ash contents. This suggests that changes in leaf composition, induced by changes in the climatological conditions, are not identical for young and old palms. This was not unexpected, as the rooting system of the younger palms is less developed than that of the older palms and, as a consequence, young palms suffer relatively more from dry periods. At such times the topsoil, in which the bulk of the absorbing roots are situated, is often completely dried out and ion uptake is restricted or may even cease altogether. In respect of the

Table 3. Analysis of variance of individually, monthly sampled palms (data as per cent of dry matter)

Description	*Degrees of freedom*	*F test of significance*				
		%K	%P	%Ca	%Mg	% ash
Total	959	—	—	—	—	—
Aggregate leaves/age	79	—	—	—	—	—
Aggregate leaves	39	—	—	—	—	—
Age	1	0·2	3·1	0·4	17·0**	4·5*
Error a	38	—	—	—	—	—
Leaf	1	298**	10·3**	263**	4·0*	3·0
Age × leaf	1	0·4	0·07	0·1	4·5*	1·0
Error b	38	—	—	—	—	—
Month	11	10·2**	23·6**	6·5**	18·8**	19·8*
Month × age	11	6·2**	6·3**	1·6	9·6**	5·8**
Month × leaf	11	2·4**	1·8	3·7**	1·2	1·7
Month × age × leaf	11	1·5	0·9	1·8	0·8	1·8
Error c	836	—	—	—	—	—

* = Significant at P = 0·05.
** = Significant at P = 0·01.

chemical composition of the leaves, it may be seen that during dry periods, the phosphorus content of the leaves of young palms is significantly lower than that of older palms. The increases in magnesium content, due to changes from wet to dry seasons, are larger for young than for old palms and the same holds good for the calcium and the ash content. With regard to the potassium content of the leaves, the interaction age × sampling time is demonstrated by the fact that increases in leaf potassium of the young palms do not coincide with changes in leaf potassium content of the older palms; *Figure 1* suggests that the reaction of older palms, as shown by increases and decreases of leaf potassium, is retarded by approximately two months.

Influence of sampling time—The sampling time has a highly significant effect on the potassium, phosphorus, calcium, magnesium and ash contents of the

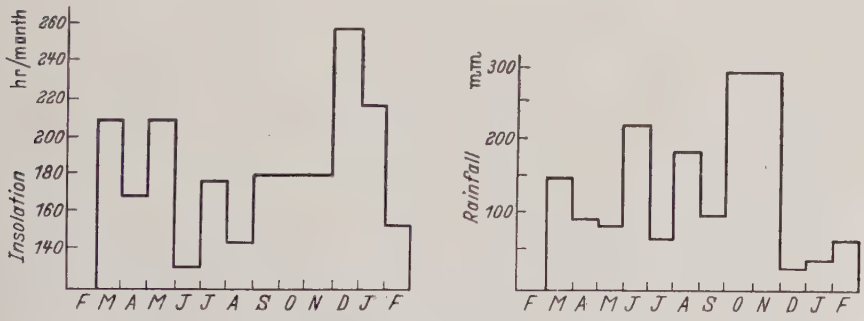


Figure 3. Insolation and rainfall, February 1953 to 1954

leaves. The wet season starts in March (see *Figure 3*) and finishes towards the end of November or early December with an interruption of a short dry season of a few weeks in June or July. When this is compared with the changes in leaf composition, it is evident that:

(*i*) the potassium content of the leaves is high during the dry season and during the small dry season in June or July;

(*ii*) magnesium is significantly higher in the months of April, July and December, coinciding with the changes from wet to dry seasons;

(*iii*) calcium values are lowest in the middle of the wet season;

(*iv*) the ash content decreases during the early part and increases slowly during the second part of the rainy season, with its lowest values in the months of July, August and September.

It should be pointed out that changes in the concentration of the several leaf components, under the influence of variations in soil and climatological conditions, need not necessarily be the same for plantations situated in other parts of the Congo. The main conclusion to be drawn from the above considerations, is, that it is essential to compare the chemical composition of samples, taken at similar periods of the year.

Sampling and analytical errors—In *Table 4*, the average standard deviations during the year are given for the potassium, phosphorus, calcium, magnesium and ash contents. It may be seen from this that the standard deviations for the ninth leaf are slightly greater than those for the first. It also appears that the data, expressed on ash, have a slightly greater standard deviation than those, expressed on dry matter. The variation coefficients in *Table 4*

Table 4. Standard deviations of several leaf constituents for the 1st and 9th leaf, mean over a period of one year

Per cent	*Mean standard deviation of 1st leaf*	*Standard deviation as a % of mean*	*Mean standard deviation of 9th leaf*	*Standard deviation as a % of mean*
Potassium ash	5·7	21	7·0	32
Potassium dry matter	0·36	20	0·39	28
Phosphorus ash	0·66	22	0·71	24
Phosphorus dry matter	0·035	17	0·029	15
Calcium ash	1·9	21	2·7	25
Calcium dry matter	0·11	18	0·13	19
Magnesium ash	1·3	27	1·6	30
Magnesium dry matter	0·077	23	0·085	25
Ash as dry matter	1·16	16	1·26	19

comprise analytical errors and the sampling variation. To obtain some information on the magnitude of the analytical errors, a series of 30 sub-samples were taken from one bulk sample and individually analysed. The variation coefficients for the determinations (standard deviations as a percentage of the mean) were found to be: potassium 4·0 per cent, phosphorus 4·8 per cent, calcium 12 per cent, magnesium 13 per cent and ash content 9 per cent.

It is clear from these that the analytical methods used are sufficiently accurate for the purposes of the work, as the sampling variation appears to be much greater than the variation resulting from the analytical technique. Further, it appears that there is little advantage in sampling more than 20 to 25 palms per bulk sample as, according to *Table 4*, a bulk sample from 20 palms has a standard deviation of the order of 4 to 6 per cent, which is of the same order of magnitude as the analytical errors.

One observation should be made concerning the accuracy of the analytical data, when expressed on ash. During our investigations it became evident that relatively large errors may arise, should the preparation of the ash

not follow a standard procedure. Differences in rate of temperature rise, initial moisture content or place in muffle furnace may have a marked effect on the quality of the ash and thus influence the final figure, expressed on ash. Another difficulty is the hygroscopic nature of the ash and the high relative humidity in the tropics; all weighings of ashes should be carried out as quickly as possible.

CONCLUSIONS

(*1*) When adopting a sampling system, for practical purposes, the morphological position of the leaf sample must be taken into consideration. Leaflets should be taken from corresponding parts of leaves of the same physiological age.

(*2*) The age of palms has an influence on the composition of the leaves. The influence of changes in climatological conditions on leaf composition is not identical for young and old palms. Moreover, the fluctuations in the composition of young palms will be greater than in old palms.

(*3*) Sampling time has a very significant effect on leaf composition; samples taken in the dry season are not comparable with those taken during rainy periods. Sampling during the changes from dry to wet seasons should always be avoided.

(*4*) The errors, involved in the chemical analysis, represent only a small fraction of the total variation. Bulk samples should consist of 20 to 25 palms.

ACKNOWLEDGEMENT

The writer expresses his indebtedness to Huilever S.A. for permission to publish this paper.

(*Received August 1955*)

Insect Infestation in Stored Rice in Nyasaland

K. F. Salmond

Research Entomologist, Lusaka, Northern Rhodesia

Rice (*Oryza sativa* L.) is still largely an African produced cash crop in Nyasaland. The main production areas are situated at lake shore level, 1550 ft above sea level, although upland rice is grown where rainfall is adequate. The rice is harvested during May, June and July and stored as head rice either in raised mudded stores known as *nkokwes*, or upon platform-like lofts within natived wellings. Keeping qualities are good with both methods of storage provided the store itself is thoroughly dried inside[1]. Flails are used to thresh the paddy which is then transported in baskets to the local grain markets.

An entomological survey of rice markets in the Northern and Central Provinces of the Protectorate was carried out during the months of July and August, 1953. At each market twenty samples were collected at random and the insects present removed by repeated sieving. At the same time some of the sieved paddy was taken for incubation in the laboratory and for moisture content determinations. Wherever possible the mudded storage containers, containing mainly new crop, were examined.

INSECT INFESTATION

W. E. Vinacke *et al.*[2] have demonstrated that brown rice which has been husked is more susceptible to insect attack than white polished rice. S. S. Easter[3] records that parboiled milled rice is more resistant to insect attack than regularly milled rice but still more susceptible than rice stored as paddy, assuming that the moisture content is comparable in all three forms. Despite the fact that paddy (*i.e.* rice before it is husked) is considered the most resistant of the various forms of stored rice, it is not immune to insect infestation. In Nyasaland paddy may be attacked in store by both primary and secondary insect pests. The market survey revealed that the most important primary pests are *Rhizopertha dominica* L. (the lesser grain borer); the small strain of *Calandra oryzae* L. (the rice or grain weevil); and *Sitotroga cerealella* Oliv. (the Angoumois grain moth). Damage by these pests was found to be slight as the rice had been brought for selling a relatively short time after harvesting. The secondary pests noted were *Silvanus surinamensis* L. (the saw-toothed beetle) and *Laemophloeus minutus* Oliv. (the flat grain beetle). These were collected from paddy showing damage effected by the primary pests already listed. Unidentifiable fragments of true ants and Diptera were also sieved out but not retained.

Samples of paddy brought back to the laboratory and incubated for ten weeks yielded very low numbers of adult insects. In all, seven *Rhizopertha dominica* L., three *Calandra oryzae* L., and two *Sitotroga cerealella* Oliv. hatched out.

Purchased paddy is bagged and stored temporarily at the markets before being transported by barge to the rice mill for processing. During the marketing season, the bags of paddy may be attacked by termites. It has been found that a 2 to 3 in. layer of fine lake shore sand or a layer of about 1 in. wood ash under the dunnage helps to reduce the incidence and severity of termite attack.

MOISTURE CONTENT

Samples of paddy from each market were placed in sealable 2 lb. *Kilner* jars, and used for moisture content determinations which were carried out in triplicate by the Brown-Duvel distillation method. The average moisture content was found to be 14·5 per cent, and the range from 12·2 to 18·3 per cent. The latter figure is high, but during 1953 very heavy rains fell, and even in July some of the rice fields were still partially flooded. Rice was harvested in some of the water-logged areas. Where the rice had been in contact with water, the outer husk was much darker in colour. A reduction in moisture content is known to take place during the period of transportation to the rice mill, so that by the time the paddy arrives at the milling centre the moisture content is from 2 to 3 per cent lower than at the markets.

CONTROL MEASURES

Insect infestation in paddy, as marketed at present, does not reveal sufficient damage to warrant immediate specific insect control measures. However, production of rice in Nyasaland is on the increase and it may become necessary to store considerable quantities of paddy or milled rice for some months under conditions favourable to rapid insect breeding. When this situation occurs those in charge of the purchasing, transporting. and storage of the rice crop should seriously consider fumigation of the stacks of bagged rice with methyl bromide under gas-proof sheets as has been done with maize[4] and other produce owned by the local Produce Marketing Board. After fumigation regular routine spraying of the stacks with an insecticide such as 50 per cent wettable DDT would be desirable at monthly intervals to minimize the risk of reinfestation by flying insects.

ACKNOWLEDGEMENTS

I wish to place on record my indebtedness to Mr. H. F. Bingham, O.B.E., Commissioner for Co-operative Development in Nyasaland, for assistance during the survey; also to the Department of Agriculture for permission to publish results obtained during my research investigations into pests of stored grain in Nyasaland.

(*Received December 1955*)

REFERENCES

[1] Barker, F. (1934). Rices of Nyasaland, *Dept. Agric. Nyas. Protect. Bull. No.* 12

[2] Vinacke, W. E. (1950). Processed Rice in Hawaii, *Univ. Hawaii Expt. Stat. (Agric.) Tech. Bull. No.* 10

[3] Easter, S. S. (1954). Infestation Control in Stored Rice, *Tropical Agriculturist*, **110,** No. 3, 217

[4] Salmond, K. F. (1954). Fumigation of Maize with Methyl Bromide, *Nyasaland Farmer and Forester*, **4,** 39

Effects of 2,4,5-Trichlorophenoxyacetic Acid on Evergreen Thicket Vegetation in Kenya

G. W. Ivens

Colonial Insecticide Research Unit, Arusha, Tanganyika

D. G. Cochrane*

East African Tsetse and Trypanosomiasis Research and Reclamation Organization, Nairobi, Kenya

An experiment was carried out early in 1954 to determine whether the arboricide 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) could be of value in preventing the re-establishment of evergreen thicket which had been cut down as a tsetse control measure. The type of vegetation in question covers large areas in valley bottoms in the South Nyanza district of Kenya and may be regarded as a secondary, relatively dry forest community characteristic of localities at 4000 to 5000 ft. with an annual rainfall of 30 to 40 in. Most of the woody species present also occur in the better developed forest communities found under conditions of somewhat higher altitude and rainfall and are widely distributed throughout the central and western parts of the country.

The thicket consisted of a very dense and thorny community of trees, shrubs and climbers growing to an average height of about 15 ft. and mostly evergreen. The relative abundance of the main woody species in the experimental area is shown in *Table 1*. The largest tree in the area was *Mystroxylon aethiopicum* and this was the only tree which had a relatively thick trunk. A few *Euclea divinorum* had also grown into medium sized trees but most of the other species were relatively thin-stemmed.

The thicket provides an ideal habitat for the tsetse fly, *Glossina pallidipes* Aust., which prevents the utilization of large areas of grazing land adjacent to the areas covered by thicket. The majority of the trees and shrubs present regenerate when felled and the new shoots produced from the stumps, root crowns or lateral roots grow very rapidly. With *Euclea divinorum* and *Acacia pennata* in particular the regrowth may be 4 to 5 ft. high a year after cutting and within a very few years a cleared area may have grown up sufficiently to support tsetse again.

If regeneration could be prevented by a chemical applied to the cut stumps it is probable that, in a few years, the cleared area would be converted to grassland. The annual grass fires which take place in the neighbourhood would then probably suffice to prevent the re-establishment of bush growth and the necessity for periodic re-clearing would be eliminated. Of the chemicals in use as arboricides 2,4,5-T appeared the most likely to be

* Present address: Zoology Department, Glasgow University.

effective and the present work was undertaken to obtain preliminary information on its potentialities.

EXPERIMENTAL SITE

The experiment was conducted in a large block of thicket known as the Ruma bush in the Lambwe valley south of the Kavirondo Gulf of Lake Victoria. The treatments were repeated in three different areas, one of which (block *C*) consisted of more mature and taller thicket than the other

Table 1. Trees, shrubs and climbers occurring in the experimental area

	Mean height (ft.)	*Mean basal diameter* (in.)	*Percentage of total*
Trees			
Scolopia *sp.*	11	1·5	21·0
Erythroxylum fischeri *Engl.* (*mostly saplings*)	6	1·1	17·0
Euclea divinorum *Hiern*	12	1·6	12·0
Mystroxylon aethiopicum (*Thunb.*) *Loes.*	16	7·2	4·6
Gymnosporia *sp.*	11	1·7	4·3
Euphorbia bilocularis *N.E. Br.*	*Frequent*	*Not treated*	
Shrubs			
Acacia pennata (*L*) *Willd.*	12	—	8·0
Grewia similis *K. Schum.*	14	1·1	2·6
Allophylus *sp.*	12	1·4	2·3
Rhus natalensis *Bern. ex Krauss.*	12	1·6	0·8
Cadaba adenotricha *Gilg. and Benedict*	10	1·3	0·6
Harrisonia abyssinica *Oliv.*	5	—	*few*
Climbers and scandent shrubs			
Scutia myrtina (*Burm. f.*) *Kurz*	14	1·6	10·0
Capparis tomentosa *Lam.*	8	0·6	5·9
Jasminum mauritianum *Boj.*	14	0·5	3·3
Jasminum dichotomum *Vahl.*	14	0·5	1·1
Carissa edulis *Vahl.*	10	—	0·3
Asparagus *sp.*	5	—	*few*
Cissus *sp.*	15	—	*few*
Unidentified	—	—	6·3

two. The three areas all contained the same species of trees. In block *B*, however (on the edge of the thicket) there were relatively few *Erythroxylum* and in block *C* there was a very high proportion of *Erythroxylum* and very few *Acacia pennata*.

TREATMENTS AND METHODS OF APPLICATION

Each of the three blocks contained ten cleared plots 5 ft. wide and 100 ft. long (just over 1/100 acre). On both sides of each plot the bush was cut back for a further 10 ft. in order to avoid the surrounding bush overhanging and shading the treated area. The plots were separated by strips of uncut bush about 30 ft. wide. In each block two plots were left as controls and on the remainder all the stumps were treated with 2,4,5-T. The plots were arranged at random within the blocks.

2,4,5-T was applied as the *n*-butyl ester dissolved in diesel oil at concentrations of 5 per cent and 10 per cent (acid-equivalent) on the same

Table 2. Percentage kills of more important tree and shrub species

Species	Scolopia *spp.*	Euclea divinorum	Scutia myrtina	Acacia pennata	Mystroxylon aethiopicum	*Total*
No. treated	556	315	270	212	122	1475
*Mean % kill**	90 (74·5)†	40 (35·4)	81 (66·2)	73 (61·7)	50 (40·9)	72·0
Control	3	0	5	0	4	2·6
2,4,5-*T* 5% *brushed*	88 (73)	29 (23)	70 (56)	55 (48)	43 (37)	62·8 (47·4)
2,4,5-*T* 5% *sprayed*	83 (70)	37 (32)	77 (59)	67 (61)	37 (27)	65·9 (49·7)
2,4,5-*T* 10% *brushed*	91 (74)	46 (38)	89 (78)	86 (67)	57 (36)	74·2 (58·4)
2,4,5-*T* 10% *sprayed*	96 (81)	57 (48)	90 (73)	88 (72)	70 (64)	84·9 (67·5)
Sig. diff. ($P=0·05$)	(10)	(13)	*N.S.*	*N.S.*	(15)	(8·5)
Cut at normal height	92 (75)	40 (36)	81 (70)	75 (62)	38 (26)	71·3 (54·0)
Cut at ground level	88 (74)	40 (34)	80 (63)	72 (61)	63 (56)	72·6 (57·5)
Sig. diff. ($P=0·05$)	*N.S.*	*N.S.*	*N.S.*	*N.S.*	(11)	*N.S.*
Applied with paint brush	89 (73)	33 (30)	79 (67)	70 (57)	49 (36)	68·0 (52·9)
Applied with sprayer	91 (76)	46 (40)	82 (66)	77 (66)	52 (45)	75·0 (58·6)
Sig. diff. ($P=0·05$)	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*
2,4,5-*T* 5%	85 (71)	34 (28)	74 (57)	62 (54)	40 (32)	64·4 (48·5)
2,4,5-*T* 10%	95 (78)	47 (43)	90 (75)	87 (69)	64 (50)	80·3 (63·0)
Sig. diff. ($P=0·05$)	*N.S.*	(9)	(12)	*N.S.*	(11)	(6·0)
Block A	99 (86)	43 (38)	81 (70)	61 (54)	58 (51)	74·7 (59·6)
Block B	94 (76)	49 (44)	88 (73)	85 (73)	48 (43)	77·2 (61·3)
Block C	69 (61)	24 (24)	70 (56)	— (—)	43 (29)	55·1 (46·3)
Sig. diff. ($P=0·05$)	(8)	(11)	*N.S.*	(11)	*N.S.*	(7·4)

* Significant difference ($P=0·05$) between species (9·6)

† Figures in brackets = per cent kill transformed to angular values.

day that the trees were cut. Each concentration was applied in two different ways (with a paintbrush and with a sprayer) to the cut surface and to the bark of stumps cut at two heights from the ground (near ground level and the height at which trees are normally cut when bush is cleared by hand labour, *i.e.* 2 to 3 ft.). Every sprayed stump was labelled and subsequently observed at monthly intervals. The treatments were applied during February and March 1954 just before the beginning of the main rainy season.

For the treatment applied by means of a paintbrush approximately 490 ml of solution per plot was used on the stumps cut at ground level and 920 ml on the stumps cut at 2 to 3 ft. There were an average of 80 stumps per plot so that the mean volumes applied per stump were 6·2 and 11·6 ml respectively. These rates of application are equivalent to 11 and 20 gal./acre of arboricide solution. On the sprayed plots larger volumes were used, *i.e.* 16·4 and 24·1 ml/stump for the ground level and normal height plots respectively. The only sprayer available at the time, however, was equipped with a nozzle producing a hollow cone spray pattern which was wasteful and not well adapted for spraying small tree stumps and it is doubtful whether the volume of solution actually reaching the stumps was any higher on the sprayed than on the brushed plots.

RESULTS

The effects of the various treatments are shown in *Tables 2* and *3*. *Table 2* shows the species which were sufficiently evenly distributed for the figures to be treated statistically and *Table 3* those of less even distribution or less frequent occurrence. The percentage kills in the tables refer to the proportions of stumps which had produced no sign of regeneration by March 1955 (*i.e.* 12 to 13 months after treatment). In order to make it possible to analyse the figures statistically, the percentage kills have been transformed to angular values by the arc sin√percentage transformation and these figures are shown in brackets.

Many of the smaller stumps had decayed and disappeared by the time of the March 1955 observation while the height of the re-growth from stumps that had not been killed was anything up to 5 ft. It is possible that some of the stumps recorded as dead may yet produce new growth but it is probable that this will occur with only a very small proportion. A more important source of error is likely to be the production of shoots from lateral roots where the main stump has been recorded as dead. Where shoots were present a short distance away from dead stumps the tree has been recorded as still living but where shoots are present more than 1 to 2 ft. away it is very difficult to determine whether these have grown from treated or untreated stumps. Thus with some species such as *Euclea divinorum* and *Acacia pennata* the percentage kill may have been somewhat overestimated.

The results given under the treatment means section of *Table 2* are the means of the results from the three blocks and the two cutting heights (*i.e.* each is a mean from six plots). The results are presented in this way in order to simplify the table and because, except in the case of *Mystroxylon*, the height at which the stumps were cut has had very little effect on the

Table 3. Percentage kills of other tree and shrub species

Species	Erythroxylum fischeri	Capparis tomentosa	Gymnosporia *sp.*	Jasminum *spp.*	Grewia similis	Allophylus *sp.*	Rhus natalensis	Cadaba adenotricha	Carissa edulis
No. treated	450	156	115	115	68	60	21	15	8
Mean % kill	90	68	62	83	60	62	64	83	83
Treatment means									
Control	22	9	0	16	0	0	—	—	—
2,4,5-*T* 5% *brushed*	93	60	42	79	53	73	—	—	—
2,4,5-*T* 5% *sprayed*	76	63	58	73	57	50	—	—	—
2,4,5-*T* 10% *brushed*	100	69	79	89	60	67	—	—	—
2,4,5-*T* 10% *sprayed*	99	79	78	93	78	61	—	—	—
Cut at normal height	97	77	59	83	68	71	—	—	—
Cut at ground level	85	62	67	83	48	54	—	—	—
Applied with paint brush	86	66	55	83	56	70	—	—	—
Applied with sprayer	96	70	68	84	63	56	—	—	—
2,4,5-*T* 5%	83	62	50	76	55	60	—	—	—
2,4,5-*T* 10%	99	74	78	91	67	63	—	—	—
Block A	100	64	57	87	69	63	—	—	—
Block B	—	73	77	89	56	76	—	—	—
Block C	87	62	53	63	62	33	—	—	—

degree of kill. The significant difference between these means at a probability level of 5 per cent, as calculated from an analysis of variance of the transformed figures, is also shown together with the differences between the means for the two cutting heights, the two methods of application, the two concentrations and the three blocks.

As stated above, *Mystroxylon* is the only species with which the height of the stump has influenced the degree of kill obtained by treatment. With this tree, 2,4,5-T applied to stumps cut at ground level has been considerably more effective than when applied to stumps 2 to 3 ft. high despite the fact that the taller stumps received a larger volume of 2,4,5-T solution. The kills with 5 per cent and 10 per cent solutions applied to stumps 2 to 3 ft. high were respectively 28 per cent and 40 per cent, while applied to stumps at ground level they were 52 per cent and 80 per cent. It is also worth noting that the height of the stump affected regeneration on the control plots so that, whereas re-growth occurred from 99 to 100 per cent of the taller stumps, with some species, especially *Mystroxylon* and *Erythroxylum*, 10 to 30 per cent of the trees cut at ground level failed to regenerate.

The differences between applications made with a paintbrush and with a sprayer are not significant. However, although the differences are small they are consistent. With all species the percentage kills are slightly greater from the spray application and with *Euclea* the difference approaches significance.

The difference between the two concentrations on the other hand is significant with three species and with the other two the difference approaches significance. There is also considerable variation in the percentage kill between the different species. Regeneration is most easily prevented with *Scolopia* and *Scutia* while *Euclea* and *Mystroxylon* are much more resistant and *Acacia pennata* is intermediate in susceptibility.

The percentage kill on block *C* (*Table 2*), the block situated in the most mature part of the thicket, is markedly lower than in blocks *A* and *B*.

Table 3 deals with the species for which the results could not be analysed statistically and shows the same features as *Table 2*. Differences between the two cutting heights and the two methods of application are generally small. There is a consistent difference between the two concentrations and the treatments on block *C* have been less effective than on the other two blocks. *Erythroxylum* and the *Jasminum* species are among the most susceptible while all the others are of moderate susceptibility.

Further information on the regeneration of the various species after treatment is given in *Table 4*, which shows the average height of regenerating shoots after 12 months and also the number of months elapsing before the first shoots appeared, for those stumps which were not killed by the treatments. Because it took about six weeks to complete the treatments while an observation of the plots could be carried out in about three days, the period between treatment and the first observation varied from about two to eight weeks. For this reason, where regeneration was present at the first observation a minimum figure of one month has been used in calculating the mean time before regeneration appeared.

It is evident from *Table 4* that where regeneration has occurred after treatment its appearance has been considerably delayed. Untreated stumps

had mostly produced fresh shoots by the time of the first observation (two to eight weeks after cutting) though *Mystroxylon* regenerated more slowly. With the treated stumps however, where fresh shoots were produced, their

Table 4. Regeneration of trees and shrubs not killed by treatment

Species		Control	Treatment				Mean of treated
			2,4,5-*T* 5%		2,4,5-*T* 10%		
			Brushed	*Sprayed*	*Brushed*	*Sprayed*	
Scolopia	*A*	1·4	6·2	8·6	6·1	5·2	6·3
spp.	*B*	10	4	3	3	6	4
Euclea	*A*	1·3	4·5	6·2	6·5	6·7	5·9
divinorum	*B*	42	39	24	26	26	29
Scutia	*A*	2·2	4·3	4·9	5·1	7·2	4·9
myrtina	*B*	11	8	14	6	6	10
Acacia	*A*	1·1	4·6	5·1	5·1	4·9	4·9
pennata	*B*	22	23	20	21	20	21
Mystroxylon	*A*	3·5	7·8	10·8	10·7	6·9	9·2
aethiopicum	*B*	4	4	3	3	5	4
Erythroxylum	*A*	1·8	1·5	*All dead*		4·5	1·9
fischeri	*B*	19	17	*All dead*		4	15
Capparis	*A*	2·1	9·3	9·6	7·1	10·5	9·0
tomentosa	*B*	15	5	12	13	10	11
Gymnosporia	*A*	1·1	8·5	4·0	9·9	8·8	7·8
sp.	*B*	10	9	9	7	8	9
Jasminum	*A*	1·9	4·2	8·2	9·5	7·8	6·6
spp.	*B*	10	13	6	9	3	9
Grewia	*A*	1·0	2·6	5·3	5·0	3·5	4·1
similis	*B*	10	11	12	7	5	10
Allophylus	*A*	1·1	7·2	10·4	9·7	9·3	9·3
sp.	*B*	4	3	4	2	4	4
Rhus	*A*	1·0	8·0	—	—	5·5	7·4
natalensis	*B*	60	12	—	—	15	13
Cadaba	*A*	1·0	—	12·0	—	4·0	8·0
adenotricha	*B*	14	—	10	—	4	7
Carissa	*A*	1·0	—	1·5	—	—	1·5
edulis	*B*	12	—	15	—	—	15
Mean	*A*	1·5	5·7	7·2	7·5	6·5	6·2

A = Mean no. of months before regeneration appeared
B = Mean height (in inches) of regeneration after 12 months.

appearance was delayed with most species for five to nine months. *Grewia similis* appears to produce new growth rather more rapidly than most of the treated species (the low figure for *Erythroxylum* is based on a number of very small stumps which were most probably missed during spraying) while,

with *Mystroxylon* and *Capparis tomentosa*, regeneration was delayed for a longer period than with the others. Regeneration has been delayed slightly longer with 10 per cent 2,4,5-T than with 5 per cent but the difference between methods of application is not consistent.

There are large differences between the species in the rate of growth of regeneration as shown by the height of the shoots 12 months after treatment. Some of these differences are probably due to differential browsing of the young shoots by game. *Mystroxylon* and *Scolopia*, for instance, appeared to be particularly palatable but, with the exception of *Euclea*, all the other species were browsed to some extent. With the very thorny *Acacia pennata* the tips of the young shoots were eaten but this species grows very quickly and once the thorns have hardened it is left alone. Although the average height of the *Acacia pennata* regrowth was only 21 in. a number of stumps had produced a widely spreading mass of shoots up to 6 ft. high. Thus despite the fact that a relatively high percentage kill was obtained with this species it formed a major constituent of the regeneration. The other main constituent was *Euclea* which was relatively resistant to chemical treatment, grew rapidly and was very little browsed.

On the other hand, *Mystroxylon* which also appeared relatively resistant (except to 10 per cent 2,4,5-T applied to stumps cut at ground level) produced little re-growth and the shoots were periodically eaten off to the level of the stump so that this species played only a small part in the production of new growth on the treated areas. *Scolopia*, *Scutia* and *Erythroxylum* were also relatively unimportant.

DISCUSSION

In this experiment, 2,4,5-T applied to stumps cut as near ground level as possible has been at least as effective, and in some cases more effective, then when applied to stumps 2 to 3 ft. high. As less than 2/3 as much chemical was required to cover the lower stumps it would appear to be best to cut the trees as low as possible before treating the stumps. On the other hand cutting trees at a level different from that at which they are normally cut would probably entail some extra supervision until the labour became accustomed to the new technique and the cost of clearing might thereby be increased.

The results show little difference between applying 2,4,5-T with a paint-brush and by spraying and, as the brushing method required less than half the volume of solution, it would appear to be the more economical. As mentioned earlier, however, a suitable spray nozzle was not available and it is probable that a fine nozzle giving a flat, fan-shaped spray would enable a more uniform coverage to be obtained with no more wastage than by brushing.

The concentrations of 2,4,5-T used in this experiment were high but the rates of application were low. The mean diameter of the treated stumps was 1·7 in. and, with application by paint brush, an average of 6·2 ml/stump cut at ground level was used. This is equivalent to 3·6 ml/in. diameter of the stumps. The most recent American recommendations for using 2,4,5-T as a stump spray usually suggest a volume of between 12 and 20 ml/in. diameter and there is a considerable amount of evidence to suggest

that better results are obtained from relatively high volumes of low concentrations than from low volumes of high concentrations. It is therefore considered probable that equally good or better results would be obtained by applying 1 per cent 2,4,5-T at 14 ml/in. diameter than by using 5 per cent at 3·6 ml/in. diameter. With 80 stumps of an average diameter of 1·7 in. per 1/100 acre plot, 14 ml/in. diameter is equivalent to approximately 40 gal./acre and 40 gallons of a 1 per cent solution requires 4 lb. of chemical. On an acre basis these rates of application are high, but in vegetation containing 8,000 woody plants to the acre, it is unlikely that lower rates would be effective.

A final point of interest is that 2,4,5-T was markedly less effective on block *C* than on the other two blocks. A possible explanation for this is provided by the fact that the trees in this block were larger than elsewhere. The average height of *Scolopia* trees in block *C* was 13·2 ft. compared to 9·7 ft. in the other blocks. Comparable figures for other species are: *Euclea* 17·8 and 9·9 ft., *Scutia* 19·1 and 11·3 ft., *Mystroxylon* 18·7 and 14·6 ft., and *Gymnosporia* 12·9 and 9·5 ft.

CONCLUSIONS

In view of the fact that effective control of *Euclea divinorum* and *Acacia pennata* was not achieved, it must be concluded that none of the treatments tested was entirely satisfactory. One year after the application of 2,4,5-T there was considerably less regeneration on the treated plots than on the controls and grasses were rapidly becoming established. The re-growth from those *Euclea* and *Acacia pennata* stumps which were not killed however was spreading rapidly and it appeared probable that in two or three years the entire area would again be overgrown. There is no doubt that the amount of labour required to re-clear the area would be appreciably reduced by 2,4,5-T treatment but not sufficiently to make such treatment economical.

It should be emphasized however that the present trial was of a preliminary nature and that, although the treatments in this trial failed to prevent regeneration of the two most troublesome species, it is possible that more effective ways of using 2,4,5-T, such as the use of higher volumes or application at different times of year, may be found. Further experiments on *Euclea divinorum* and *Acacia pennata* are in progress.

(*Received December 1955*)

Salvinia Auriculata *Aubl.: the Chemical Eradication of a Serious Aquatic Weed in Ceylon*

R. H. Williams

Shell Company of Ceylon Limited, Colombo

The aquatic fern *Salvinia*, a scheduled weed under a Ceylon Government Ordinance, has rapidly developed into a serious threat to the cultivation of food crops throughout the length of the western seaboard of Ceylon. During the last three decades there have been three major aquatic plants adversely affecting the cultivation of paddy in the island, namely water hyacinth (*Eichornia crassipes*), bulrush (*Typha angustifolia*), and now *Salvinia*; the two former have been partially eradicated by manual methods although today there are again signs of a considerable recurrence of water hyacinth. In all the infestations vain attempts were made by village cultivators to remove the plants manually but ultimately the responsibility for the eradication has always fallen on the State.

Salvinia (in Ceylon the major infestation is *Salvinia auriculata* Aublet) has not responded to manual methods of control which would give any suggestion of permanency. Some two years ago attention was turned to the possibilities of the use of one of the contacts, selective or total herbicides which were then becoming so widely used throughout the world.

This paper attempts to summarize the pattern of behaviour of the *Salvinia* plant throughout the paddy lands and waterways since its introduction into the island some 16 years ago. An account is given of the research carried out by the author with the assistance and co-operation of the Departments of Agriculture and Food Production of the Ceylon Ministry of Agriculture to discover a suitable herbicide and methods of application.

Results have revealed a satisfactory and relatively economic method of chemical control which has now been translated by the government into a *Salvinia* Eradication Campaign.

INTRODUCTION AND SUBSEQUENT SPREAD OF SALVINIA IN CEYLON

There are two *Salvinia* species prevalent in Asia, particularly in east and west Bengal, Assam and Burma, namely *S. cucullata* and *S. natans*. In 1933 an additional species, *Salvinia auriculata*, was introduced into the Royal Botanical Gardens, Calcutta, on a plant exchange basis from Germany; the plant originated in South America, Brazil being the commonly quoted country of origin. In 1939 by request of the university authorities a few plants of the three species were sent to Ceylon for botanical studies at the university premises in Colombo. It is presumed that on completion of these studies the plants were discarded and ultimately must have survived and become water-borne since in 1942 Dr W. R. C. Paul, then Divisional

Agricultural Officer, Western Province, first recorded seeing quantities of the plant in water around Kolonnawa, a north-eastern suburb of Colombo. From this unintentional distribution, has developed a menace which has affected thousands of acres of the richest paddy lands of Ceylon, and caused difficulties to inland waterway operators through blocking the canals with masses of the *Salvinia* plant; silting up of irrigation channels and damage to culverts and bridges by blocking and subsequent flooding is also experienced.

The initial *Salvinia* infestations existed in areas where there was flowing water and they were of no nuisance value; other plants continued to multiply in small areas of static water. It should be noted that many years ago, during the period of Dutch occupation, the San Sebastian Canal was constructed as a transport and irrigation facility, stretching from Kalutara, 25 miles south of Colombo, to Puttalam, just over 80 miles north of the City. This canal is from a few hundred yards to several miles inland from the coast and undoubtedly it was, and still is, mainly responsible for carrying the infestations to different areas in the island. During the course of the major flood of 1947 the level of the canal rose to unprecedented heights, flooding adjacent land for several miles on either side of its normal course; carried with these flood waters was the rapidly multiplying *Salvinia* plant. In addition to the major affected areas which are all linked together through the canal and river systems, there are other minor and major infestations of a self-contained nature where originally a few plants were introduced by the agency of man, animal or bird life.

A recent aerial survey, covering the length of the canal from Colombo northwards, confirmed that there are *Salvinia* plants to a greater or less extent the whole length of the canal. It was markedly noticeable that, in all but a few instances, other infestations were adjacent to the canal or connected in some way with the canal.

The rapid growth exhibited by *Salvinia auriculata* has undoubtedly overcome to a great extent the two other related species and all other water plants as, at the present time, the entire infestation appears to be *Salvinia auriculata* with a few plants of *Salvinia natans* included; *Salvinia cucullata* has yet to be isolated. The infestation has grown on lines similar to that exhibited in the Calcutta Botanical Gardens where this one species has already ousted most other aquatic plants in the garden lakes but, as far as can be ascertained at the time of writing, *Salvinia auriculata* has been carefully imprisoned within the Botanical Gardens. The superintendent published a Botanical Handbook in 1936, just three years after the initial introduction of the plant, in which he remarked ' In the course of time if this species happened to find access into ponds outside it would add to the list another free-floating water pest of Bengal, but of course not such a formidable one as water hyacinth '. He was referring to the possibility of *Salvinia auriculata* escaping from the Botanical Gardens. These words are painfully true of the situation as it exists in Ceylon today.

Salvinia affects cultivation in two ways, first by actual infestation of the paddy field itself making it difficult for the cultivator to sow and reap his paddy and, secondly, by the blocking of irrigation and drainage channels, preventing their normal functions which are so essential to paddy cultivation. When the infestation is in the paddy field itself, the initial problem is not so

difficult because it is only necessary to remove the plant before cultivation commences, and to continue this process ensuring that the field is always cropped. However, if the affected field is allowed to remain fallow for part of the year, or longer, the problem will become considerably aggravated and the plant will establish itself in the field and in the irrigation channels; simple manual methods of removal will become difficult and costly. Ultimately the situation degenerates and the land is abandoned to *Salvinia*.

Government statistics record that there are some 700,000 acres of paddy land cultivated in the island during the *Maha* season, and some 300,000 acres of this is used during the *Yala* season. The *Salvinia* problem exists in the most thickly populated region of the country and thus affects many of the richest paddy areas. At the conclusion of an island-wide survey during April to August 1954 it was estimated that *Salvinia* affected some 22,000 acres of cultivable land and at least 2000 acres of waterways.

MORPHOLOGY AND HABITAT OF THE PLANT

The family Salviniacae contains two genera, *Azolla* and *Salvinia*, both of which are free-floating plants. We are concerned only with the latter genus in this paper and more particularly with *Salvinia auriculata*. As far as can be ascertained the first reference to *Salvinia* was made in 1846 by a German scientist and, since that year, further papers have been written on different aspects of the genus but no detailed field studies have been recorded.

The plant normally floats freely on water surfaces but can survive on mud and will withstand drying over short periods although prolonged drought kills the plant. It has a high productive capacity but nowhere in the New World have serious infestations been reported; in Ceylon, however, the plant spreads very rapidly, ousting and finally eliminating all other water plants.

Morphology—A free-floating delicate stem bears two types of leaves, aerial leaves, cordate at base and bright green in colour, and submerged water-leaves, brownish and root-like in structure. The leaves are produced in groups of three, each group having two aerial leaves situated dorsilaterally and the third, the water-leaf, is much dissected and in the ventral position. At each node two buds of unequal size arise, the larger functional bud developing into a lateral shoot whereas the smaller bud on the opposite side of the stem remains dormant and undeveloped; the functional bud is found on alternate sides of the stem, thus giving alternate lateral offshoots. There are no true roots formed although the ventrally placed dissected leaf is often mistaken for the root system.

Two distinct types of dorsilateral leaves are produced; the juvenile aerial leaves possess petioles, float in a horizontal plane, are dark green in colour, oval in shape and have rudimentary papillae and hairs. The mature aerial leaves are bright green in colour, deeply cordate at base, bisected on either side of the midrib and with each quadrant turned through 90° and then brought into a vertical stance, interleaved and face to face. The under surface is covered with hairs and likewise the upper surface is hairy, groups of four hairs being borne by each papilla; the hairs prevent the leaf surface from becoming wet and are $\frac{1}{2}$ to 1 mm in length; stomata and air-chambers are also present on the upper surface.

The submerged ventral leaf has a short petiole which projects vertically downwards from the main stem and from the distal end this leaf is dissected out into sterile segments, cylindrical and with hairs, averaging 38 in number and some 7 in. in length; these segments greatly resemble true roots. The central one to eight segments of the ventral leaf of *Salvinia auriculata* are fertile and bear sporocarps whereas in *Salvinia cucullata* only one fertile segment appears to be present. The sporocarps are arranged alternately and average eight to a leaf segment, there being two types, the mega- and micro-sporocarps, both of approximately equal size, *i.e.* about 2 mm in length,

Figure 1. Plant of Salvinia auriculata *showing secondary laterals and the much dissected ventral leaf as the ' root-like ' structures beneath the plant*

globular in shape and covered with minute hairs. Generally only one mega-sporocarp is present and is borne at the base of each segment attached to a more lengthy stalk. An average of 31 mega-sporangia are contained in the mega-sporocarp and some 560 micro-sporangia in the micro-sporocarp; these numbers are very variable but in all cases a high degree of under-development and abortion occurs.

Habitat—It is interesting to record the forms adopted by *Salvinia* under different ecological conditions. Where the water area is very limited crowding of the plant is likely to occur and apical development only is shown by the mature plant under optimum growth conditions; the newly formed leaves adjacent to the apex are similar to mature leaves except in size. With the provision of a larger free water area, primary laterals are produced from the main stem. It is only under conditions of open water that second-degree laterals develop on the primary laterals; the dorsilateral or aerial leaves of the lateral offshoots are of the characteristic juvenile form, possessing a small petiole and being slightly keel-shaped, superficially

resembling *Salvinia natans*. Generally the juvenile plants in the field are found in isolated water patches, particularly close to dry land where an old mature plant is likely to have lain. The transformation of the juvenile dorsilateral leaves to the mature leaf form is accomplished in a matter of weeks, the petiole disappearing and the central midrib splitting down the centre. One quadrant of each of the two leaves then moves across the face of the other as though in series, meanwhile all four sections coming into a vertical stance to produce the characteristic mature plant formation.

HAND REMOVAL AS A METHOD OF CONTROL

The only method by which the ordinary cultivator can hope to continue cultivation of his domestic crops in the event of an infestation of *Salvinia* is by removing each plant by hand, a tedious and laborious job that is only a temporary expedient as, ultimately, the affected areas will be entirely overrun.

It will be recalled that the plant propagates itself by vegetative methods and that the slightest movement of a plant possessing primary or secondary laterals will generally be sufficient to cause the severance of the latter from the mother plant. The cultivator cannot conceivably remove each separate small piece of *Salvinia* intact and his work will only temporarily alleviate the problem, possibly for long enough to grow a few crops of paddy. Certainly in a matter of a few years the area will be heavily infested and inundation of the land will be likely to occur due to blocking of drainage facilities, particularly if the land is fallowed at any time.

In 1952 the Government inaugurated a '*Salvinia* Week' with the aim of clearing several thousands of acres of land and waterways. The *Salvinia* plants were swept by net and boom to a convenient place for hand removal and dumped in vast piles on adjacent land; within a few months complete re-infestation has occurred since the very act of removal by hand caused severe disintegration of the plant. Thus it has been recognized that hand removal is a very temporary expedient but it was the only method practised in the absence of any chemical or biological control measures. In the meantime the overall infestations had increased leading to the wholesale abandonment of affected areas.

MANURIAL VALUE OF SALVINIA

With the adoption of carefully controlled conditions the *Salvinia* plant could well become a ready and valuable source of organic fertilizer for annual and perennial crops. In the case of the annual irrigated rice crops the matured *Salvinia* would first have to be thoroughly dried before use, whereas in the latter case, of non-irrigated crops, bearing in mind the extent of coconut, rubber and cocoa plantations in the island, the disposal of *Salvinia* as a green mulch might be expected to improve the conditions for crop growth.

It must be appreciated, should the above uses be contemplated, that strict control would have to be exercised in order that breeding areas should be carefully contained so that there would be no fear of spread from these areas in times of flood. Such a method is practised by one of the most

progressive estate owners in Ceylon and with marked effect on his coconut palms.

Hand removal for any other purpose than the above is to be strongly deprecated since only a very temporary control is effected and, in most cases, transference of the plant to unaffected areas will be occasioned.

The results of chemical analyses on *Salvinia* carried out by the Department of Agriculture are given in *Table 1.*

It will be appreciated that ten times the weight of green material will be required to produce one ton of dried *Salvinia.* The labour, time and costs involved far outweigh the value of the dried material and the method is rarely adopted.

Table 1. Results of chemical analysis of Salvinia

	Fresh Material %	*Moisture Free Basis* %
Moisture	89·30	—
Organic matter	6·07	56·72
Ash and sand	4·63	43·28
Nitrogen	0·09	0·84
Potash (K_2O)	1·156	1·46
Phosphoric acid (P_2O_5)	0·022	0·207
Lime (CaO)	0·042	0·386

PUBLIC HEALTH PROBLEMS ARISING FROM SALVINIA INFESTATIONS

Salvinia auriculata by its profusion of growth tends to choke surface drains causing stagnation of water often near to human habitation. In addition water collections covered with *Salvinia* infestations provide shelter and protection to mosquito larvae and assist in their multiplication. In Ceylon, *Pistia stratiotes,* commonly referred to as ' water lettuce ', is prevalent and the chief aquatic plant on which *Mansonia* mosquitoes breed; the *Mansonia* species of mosquitoes are the vectors of rural filariasis. The eggs are laid on the under-surface of *Pistia* leaves and, when hatched, the larvae attach themselves to the so-called roots of the plant. *Salvinia* might well replace *Pistia* in this life cycle and indeed the larvae have been observed attached to the ventral leaf of *Salvinia* plants. Observations and experiments on this aspect have been carried out by the Filariasis Division since 1951.

However, it is recorded that the egg masses found on *Salvinia* are small and occasional rather than the large and abundant infestations maintained on *Pistia.* It appears probable that, due to the extremely thick coverage exhibited by *Salvinia,* there is less chance for the adult mosquito to approach the underside of the leaves for egg-laying purposes, whereas, in *Pistia,* the much less rapid rate of propagation and plant compaction enables ease of penetration by the mosquito vector. A heavy perennial population of adult *Mansonia* mosquitoes is required to maintain and transmit rural filariasis, but there has been no evidence so far either in the field or in the laboratory to show that *Salvinia* infestations can maintain the requisite dense population. The Health Department is watching the problem very carefully in case there are indications that *Salvinia* is replacing the *Pistia* plant as a host.

Regular bi-annual sprayings of the *Pistia* plant are carried out by the Filariasis Control Division of the Ceylon Ministry of Health using a selective

herbicide; it would appear however that the total acreage of infestations has not decreased appreciably. The method adopted has been for teams of labourers, equipped with ' Hudson ' pressure-retaining knapsack sprayers, to be responsible for spraying defined areas under the supervision of a Filariasis Inspector and his foreman.

CHEMICAL CONTROL OF SALVINIA

Discussions were held with various research personnel in Ceylon, all of whom have been concerned with *Salvinia* since its appearance, but not one person reported the presence of a normal fern prothallus on which the archegonia and antheridia could be produced. Additionally, scientific personnel in Ceylon and India were unable to induce the profuse numbers of spores produced to germinate in artificial culture. Thus it was assumed that the plant had adapted itself by propagation only by vegetative methods in the favourable circumstances presented in Ceylon. If the above assumption proves correct, and it appears to be so under present natural growing conditions, then hand removal of the *Salvinia* plant with its inevitable re-infestation is undoubtedly a major factor in the continued distribution of *Salvinia* over the country; a method must be evolved whereby the plant can be destroyed *in situ.*

If the present sporophytic generation could be eliminated and, since no gametophytic generation occurs, the plant could be entirely eliminated. A study of the available literature revealed that no attempts had been made to destroy the plant with chemical weedkillers. Naturally, under the conditions of growth, it would be highly unlikely that a 100 per cent eradication could be effected unless thorough and continued chemical spray methods were evolved and practised over a number of years. At the conclusion of these preliminary discussions and personal observations, the author initiated experiments with the herbicides available in Ceylon.

The approach to the problem was two-fold, to find a suitable chemical, if available, and its dosage rate, at the same time adapting or designing spray equipment that could be used in the situations in which the *Salvinia* plant is found to be growing. The herbicides available could be classed as follows: (*a*) selective weedkillers based on MCPA and the amine and ester salts of 2,4-D. (*b*) mineral oils such as kerosene, diesel and gas oils. (*c*) fortified mineral oils.

To all these formulations when used there was added Shell *Teepol*, a synthetic detergent which assisted the wetting of the hairy upper surfaces of the leaves.

Initial laboratory tests were carried out with the chemicals available and each laboratory test was followed up with small scale field plot tests. Concurrently with this early work a number of different types of spraying equipment were used, in addition to a variety of spray nozzles, to produce the desired effects. The chemicals tested were:

(*a*) The amine salt of 2,4-Dichlorophenoxyacetic acid (5 lb. of acid per imperial gallon).

(*b*) Ethyl butyl ester of 2,4-Dichlorophenoxyacetic acid (9 lb. acid per imperial gallon) dissolved in an aromatic oil together with a small quantity

of non-ionic emulsifier to ensure that the product would emulsify when diluted in water.

(*c*) 2,methyl4-chlorophenoxyacetic acid.

(*d*) TP.5059 (an emulsible oil containing 12 per cent pentachlorophenol).

(*e*) EF.140 (an emulsible oil containing 14 per cent pentachlorophenol).

(*f*) Shell Diesoline.

(*g*) Shell ' Rising Sun ' illuminating kerosene.

Figure 2. Spraying equipment conveniently placed in a carrying cradle rests on the bank within 300 ft. of the sprayers

Each of these formulations were applied at the following rates:

(*i*) 1/8th to one gallon of 2,4-D or MCPA formulation per acre.

(*ii*) 1/8th to 10 gallons of TP.5095 or EF.140 per acre.

(*iii*) Shell Diesoline and Kerosene at 40 gal./acre.

(*iv*) Quantities of the selective and pentachlorophenol formulations were mixed and a comprehensive series of trials laid out.

Initial plot sprayings were carried out with the aid of the following equipment: (*a*) *Colibri* pressurized knapsack sprayer with a *Teejet* 8002 nozzle. (*b*) *Savol* hand-operated knapsack sprayer using a *Lyunet* nozzle No. 0·5/0·5. (*c*) A Duiker *Mistblower* using a Duiker atomizer. Each formulation was used with each machine at each concentration; the trials being conducted over a period of time from August 1952 till December 1953.

Results of these preliminary tests indicated a number of lines on which further studies might proceed:

1. With certain of the chemicals and with the equipment used juvenile *Salvinia* plants could be eradicated.

2. With the equipment used and the chemicals under trial mature *Salvinia* plants were not affected.

3. The selective herbicides based on 2,4-D and MCPA were ineffective at all concentrations (1, 2, 4, 6 and 8 pints per acre of the formulations).

4. The straight mineral oil fractions were ineffective insofar as several applications were required, but in this instance severe pollution of the water occurred making their use impracticable.

Figure 3. Tittawela Tank, Kurunegala District, showing a clear water surface from which Salvinia *has been eradicated with Shell* Salvinia *Weedkiller*

5. The fortified mineral oils containing pentachlorophenol were effective against young plants, there being no visible difference in control between the TP.5095 and EF.140 formulations.

6. Degrees of control were obtained in the plots sprayed with the selective and total weedkillers formulated together; a higher percentage of destruction being recorded the greater the concentration of pentachlorophenol in the mixture.

7. In no case were any of the formulations considered effective against mature plants.

The results suggested that if the juvenile plant was destroyed by the pentachlorophenol formulations and yet the mature plant was unaffected then a more detailed study of the plant structures and reaction to spraying would be worth while. As indicated in the section describing the morphology of *Salvinia auriculata*, it would appear that the denseness of the hairs on the upper leaf surface combined with the more or less vertical position of the dorsilateral leaves would tend to deflect any liquid sprayed off the plant.

A further complication is the positioning of the functional bud which is well protected by the mass of aerial leaves. These botanical studies pointed to the fact that increased pressures and volumes would be required in order that the liquid should reach the active tissues, and thus it was concluded that power spraying equipment should be tried.

To implement the above observations a mechanized spray unit, designed for re-charging batteries of knapsack sprayers, was obtained and a few simple modifications introduced. The unit, a Four Oaks Spraying Co. machine, consists essentially of a $\frac{3}{4}$ hp 4-stroke petrol engine driving a simple gear pump with a capacity of 4 gallons per minute at 550 r.p.m. and producing a nozzle pressure of 100 lb. per sq. in. Rubber hose lengths, hand-operated lances and Four Oaks Woodford special cone spray nozzles were used.

A further set of test plots were laid down incorporating the formulations described above but excluding the straight mineral oil fractions, the formulations being sprayed with the mechanized pump unit. Each plot was 1/40 acre in extent containing both juvenile and mature plants ranging over a water depth of 0 to 5 ft., and observations were carried out over a period of three weeks following the initial application of the spray liquid. The results achieved were:

1. No effect was recorded from the selective weedkillers, whatever the concentration used.

2. Juvenile *Salvinia* plants were destroyed when the pentachlorophenol concentration was as low as 4 gallons of formulation per acre.

3. The degree of control of mature plants using either of the pentachlorophenol formulations by themselves or in the mixtures was directly proportional to the concentration of pentachlorophenol.

4. An estimated 90 per cent control of mature plants was given using the equivalent of 10 gallons of either EF.140 or TP.5095 formulation diluted in water to 200 gallons of spray liquid.

It was thus concluded that if the three factors appertaining to the mechanized unit were examined, *i.e.* volume, pressure and spray pattern, then possibly the control would be approaching that of total destruction. From continued observations it appeared that a second spray would be necessary some 14 to 21 days after the initial spraying when any buds that were to develop would have done so depending, of course, on weather conditions.

At this juncture it was decided that the results were promising enough to inform the Ceylon Ministry of Agriculture and to obtain their support for further investigations. The Minister of Agriculture & Food instructed the Departments of Agriculture and Food Production to cooperate and assist us in our proposition to lay out larger trials. A number of affected paddy and tank areas were surveyed in which *Salvinia* was growing under widely different conditions of water depth and density; for the largest of these areas, of 30 acres in extent, Government agreed to pay the costs of the weedkiller and labour as, in parallel with these experiments their Medical, Veterinary, Fishery and Botanical Officers would make necessary tests and observations with regard to toxicity of the herbicide to man, animals and

fish. Additionally a study was made on any phytotoxic problems that might arise when paddy crops are sown after the *Salvinia* had been eradicated.

The mechanized unit was re-designed around the basic structures of the petrol engine and gear pump and in addition further spraying work adequately proved that three hand-operated lances each with a *Boomjet* nozzle (0C06 tip) was superior to a single 15-nozzle rigid boom. For spraying *Salvinia* over deep water areas a pontoon type raft was specially designed (see *Figure 4*).

Figure 4. The same view of Tittawela Tank as in Figure 3, showing heavy Salvinia *infestation before spraying. Note the spraying equipment mounted on a special pontoon.*

Two sprayings of the newly designated 'Shell *Salvinia* Weedkiller' (12 per cent pentachlorophenol plus wetting agents in an oil emulsion) were applied at a 14 to 21 day interval, at the rate of 10 gallons of the weedkiller diluted to 190 gallons with water and sprayed at 200 gallons of spray liquid per acre. It was observed that less than 50 per cent of the total area required a second spraying and, within three weeks of the second spraying, both young and mature *Salvinia* plants, had been completely and effectively destroyed, the plants sinking below the water surface where possible. After a period these plants disintegrated and were of no further hindrance.

TOXICITY AND PHYTOTOXICITY PROBLEMS

During the whole course of the experiments careful observations were made by the author and by the official Government personnel.

On the human toxicity angle no effects were reported to humans constantly in contact with the diluted spray; it would appear that since the spray personnel are in continuous and intimate contact with water any spray liquid touching their skins is quickly removed. Care was used when handling the concentrated formulation and immediate washing with plenty of water was strictly adhered to. Water-buffalo occasionally wandered through sprayed areas but this was avoided as far as possible in order that the sprayed areas should not be disturbed; no untoward effects were reported on these animals and they could not be induced to drink the sprayed water until some weeks after the initial sprayings.

In water of less than 12 in. depth small fish were destroyed but in the deeper areas no deaths were recorded unless the fish were at the water surface at the time of spraying. Frogs, tortoise and small water snakes were particularly susceptible to the diluted spray liquid. Within a matter of weeks after heavy *Salvinia* infestations on tanks had been cleared, normal line-fishing by the local inhabitants was resumed.

Observations with regard to phytotoxicity problems showed that paddy seed could be broadcast within three days of a second spraying and good germination of seed was reported if planted within seven days of either the first or second sprayings. One paddy crop has been harvested from several cleared areas and it would appear that an above-average crop has been produced.

SALVINIA ERADICATION CAMPAIGN

Following the results of the two years' investigations carried out by the Shell Company of Ceylon, the Government decided to inaugurate a *Salvinia* Eradication Campaign on an initial 5000 acres in the northern areas of the island. This Campaign was initiated in January 1955 and will continue for much of the year except when monsoon conditions preclude actual spray work. This self-contained area is being cleared with the aid of seven units, the pump and raft designs and techniques employed being as noted above. Recently (April 1955) a further three units have been constituted, each unit equipped with a piston-type pump as opposed to the earlier gear-pumps.

The results to date have shown the complete effectiveness of the weedkiller, although the work is somewhat arduous for the spray labourers, but there seems no possible way at the moment whereby the direction of the spray can be carried out other than by human agency. An effort is being made to encourage the local population to purchase knapsack sprayers and to maintain vigilance over the sprayed areas, in order that any future appearances of the *Salvinia* plant may be eliminated at the earliest possible moment. A tremendous amount of goodwill is being engendered as the cultivators themselves are seeing that by co-operating with the spray units they will soon be able to bring back into bearing land which has been infested with *Salvinia* and abandoned in many cases for some eight years or more.

The direction of the campaign is vested in one officer of the Department of Food Production, a branch of the Ministry of Agriculture, and it is expected that in time, provided the excellent initial results are maintained, further units will be slowly added in order that the total area of *Salvinia* throughout the island shall be adequately and quickly eliminated. Even with the most careful spraying, however, it is extremely unlikely that the *Salvinia* plant will be completely eradicated as some of the areas are virtually unapproachable to spray teams. However, by containing the plants in such areas and with constant vigilance further depredations can be avoided.

ACKNOWLEDGEMENTS

Appreciation for advice and assistance is expressed to the Minister of Agriculture and Food, the Hon. Mr J. R. Jayewardene, M.P., Mr N. Manicka Iddaikkadar, and Mr W. Parthirana, Director and Assistant Director respectively, Department of Food Production; to Dr A. W. R. Joachim and Dr W. R. C. Paul, Director and Deputy Director, Department of Agriculture. Acknowledgement is made to Mr J. E. Senaratne, Systematic Botanist, Department of Agriculture, and Mr R. N. de Fonseka.

The Managing Directors of the Shell Petroleum Co. Ltd., London, have kindly given their permission for this paper to be published.

(*Received November 1955*)

Effect of Defoliation on Two Clones of Derris elliptica

W. C. Kennard

Federal Experiment Station, United States Department of Agriculture, Mayaguez, Puerto Rico

Roots of the tropical leguminous plant, *Derris elliptica* (Roxb.) Benth., are an important source of rotenone, a valuable insecticide which is relatively non-toxic to warm blooded animals[1]. Derris plants are grown usually on a two to two and a half year cycle, because the maximum percentage rotenone is reached when the plants are 26 months old, and yield of roots increases with age[2]. Harvesting is difficult due to the mass of leafy vines produced during this prolonged growing period. R. H. Moore[3], studying the effect of exhausting food reserves, cut 27-month old plants of *Derris elliptica* variety Changi No. 3 back to stumps and periodically removed the foliage as it appeared until the production of new leaves had practically ceased. He reported that the carbohydrate reserves were exhausted, but that the rotenone content of the roots was not affected. Rotenone once deposited apparently is not translocated or metabolized. Agronomic practices such as chemical defoliation, if they did not affect the rotenone content of the roots adversely, would facilitate harvesting.

This experiment was initiated to determine the effectiveness of several defoliation treatments and their influence on the insecticidal content of derris roots.

METHODS

Cuttings approximately $\frac{3}{8}$ in. in diameter and 12 in. long from the clones Sarawak Creeping and MG-6 were placed in a sandbed shaded with coconut palm leaves. Approximately four months later the rooted cuttings were planted in a Toa silty-clay loam soil to which a complete fertilizer had been added. Each rooted cutting was cut back to two full leaves when dug from the propagating bed and planted at 2 ft. intervals in rows 3 ft. apart. The two varieties were set out in identical blocks with sufficient plants of each to replicate the defoliation treatments. All plants were mulched, fertilized, and weeded as necessary during the two and a half-year growing period.

In early December, 1954, plots of five uniform plants replicated four times were selected from each of the clones. Each plot was bordered on all four sides by non-treated plants. The following treatments were applied on 21 December 1954: 12·0 per cent AERO Cyanate* (91 per cent potassium cyanate), 0·02 per cent 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), 0·02 per cent 2,4-D (2,4-dichlorophenoxyacetic acid), mechanical defoliation (leaves removed manually), and control (leaves not removed). The chemicals were applied with a two gallon, stainless steel knapsack

* Manufactured by American Cyanamid Co., New York, U.S.A.

sprayer, and each plant was sprayed to run-off. Sheets of plastic were held around each sprayed plot to prevent drift from reaching adjacent plants.

On 24 January 1955 all plant tops were cut off, and the roots excavated, care being taken to secure as much of the root material as possible from each plant. The roots from the five plants of each replication were washed in running water, composited, and the fresh weight determined in grams. The roots were then cut into small pieces, placed in the shade until snap dry, and the weight determined. The dried roots were ground through a 40-mesh screen in a Wiley mill, and then analysed in duplicate by standard AOAC methods[4] for total chloroform extractives and for percentage rotenone. Although the rotenone content alone usually is used as the basis for determining derris root value, variable amounts of toxic compounds closely related chemically to rotenone occur in the roots. These compounds, together with rotenone, are included in the chloroform extracts.

RESULTS AND DISCUSSION

All plants sprayed with AERO Cyanate were completely defoliated one week after spraying, and new growth began two to three weeks later (see *Figure 1*). Plants sprayed with 2,4,5-T were about 50 per cent defoliated

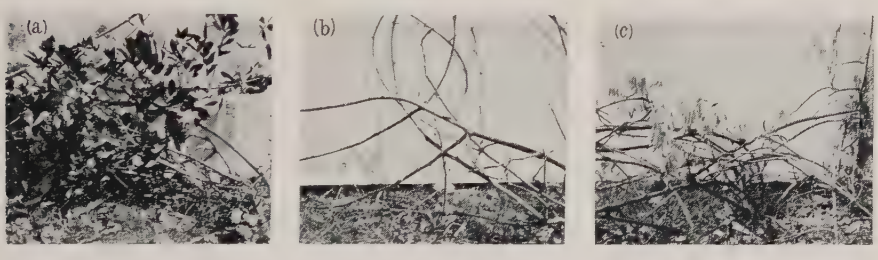


Figure 1. Effects of AERO cyanate spray applications on foliage of the derris variety MG-6: a, *typical plant before treatment;* b, *appearance one week later;* c, *amount of new growth four weeks after treatment*

one week after spraying and were completely defoliated three weeks later. Death of vine tips and small lateral branches was associated with defoliation in this treatment, but the plants remained alive. The number of new buds proliferated also was reduced in comparison with the other four treatments. The 2,4-D spray caused approximately 30 per cent defoliation that persisted up to the end of the experiment, but death of the branch tips did not occur. Plants from which the leaves had been removed mechanically showed a small amount of regrowth one week later, and by four weeks were covered with a new flush of growth. The untreated control plants continued to grow and send out new leaves so that an average increase in the amount of foliage of about 25 per cent occurred.

The yields per plot were quite variable, but the defoliation treatments did not cause significant differences. As shown in *Table 1*, the two clones, Sarawak Creeping and MG-6, produced an average of 521·7 and 618·4 gm of fresh roots per plot, respectively. The variety MG-6 averaged 37·9 per cent dry weight, as compared with 26·7 per cent for Sarawak Creeping.

Table 1. Root yields of the derris clones Sarawak Creeping and MG-6 defoliated by various means*

Treatment	Derris clone			
	Sarawak Creeping		MG-6	
	Fresh weight	Dry weight	Fresh weight	Dry weight
	gm	gm	gm	gm
AERO Cyanate (12·0%)	671·2	170·4	689·2	260·7
2,4,5-T (0·02%)	339·5	98·2	759·2	274·8
2,4-D (0·02%)	578·9	154·8	616·1	247·0
Defoliated mechanically	506·3	131·9	515·6	186·0
Control	512·4	140·6	512·0	204·3
Mean	521·7	139·1	618·4	234·6

*Each figure represents average yield of four replications of five plants each.

Table 2. Percentage total chloroform extractives (TCE) and rotenone from roots of the derris clones Sarawak Creeping and MG-6 defoliated by several methods

Treatment	Derris clone			
	Sarawak Creeping		MG-6	
	TCE	Rotenone	TCE	Rotenone
	Per cent	Per cent	Per cent	Per cent
AERO Cyanate (12·0%)	18·86	5·41	18·60	6·65
2,4,5-T (0·02%)	15·17	5·33	16·33	6·16
2,4-D (0·02%)	16·71	4·81	16·27	6·49
Defoliated mechanically	18·62	5·89	16·82	6·92
Control	15·75	4·23	17·62	6·78
Mean	17·02	5·13	17·12	6·60

Each figure represents the average of four replications of five plants each.

The differences in yields of insecticidal material (*Table 2*) were found to be not significant when analysed statistically. The total chloroform extractives were approximately the same for the two clones used, but MG-6 gave a mean of 6·60 per cent rotenone compared with 5·13 per cent for Sarawak Creeping. Although not significant statistically, the highest percentage rotenone for both clones was found in plants from which the leaves had been removed mechanically. The plants which were treated with AERO Cyanate yielded the highest percentage total chloroform extractives. In the case of MG-6, the percentage rotenone was approximately the same for the control plants and for those treated with AERO Cyanate. In the variety Sarawak Creeping, however, the rotenone values for control and AERO Cyanate-treated plants were 4·23 and 5·41 per cent, respectively.

These results would indicate that chemical defoliation is not detrimental to the rotenone content of derris roots and, further, that mature derris plants of the varieties Sarawak Creeping and MG-6 can be defoliated completely by AERO Cyanate applications without causing injury or death of the vines. Such a defoliation procedure would be desirable commercially, as it greatly facilitates harvesting derris roots.

SUMMARY

Mature plants of two *Derris elliptica* clones, Sarawak Creeping and MG-6, were sprayed with solutions of AERO Cyanate, 2,4,5-T, and 2,4-D, and were defoliated by mechanically removing the leaves. Comparisons with untreated control plants showed that AERO Cyanate (12·0 per cent) affected complete defoliation within one week after application without damage to the plants. 2,4,5-T (0·02 per cent) caused defoliation within three weeks after application, but was associated with death of vine tips and small lateral branches. Sprays of 2,4-D (0·02 per cent) caused only approximately 30 per cent of the leaves to drop.

None of the treatments had any effect, statistically, on the percentage total chloroform extractives or percentage rotenone of the roots. The values for these two constituents from roots of plants treated with AERO Cyanate, however, were equal to or greater than the percentages found in roots of the control plants.

AERO Cyanate sprays, therefore, can be used to facilitate harvesting derris by causing complete leaf drop without damage to the plants or adversely affecting the insecticidal content of the roots.

ACKNOWLEDGEMENT

The author is indebted to Mr B. C. Collazo for assistance in making the chemical analyses.

(*Received December 1955*)

REFERENCES

[1] Roark, R. C. (1941). Present status of rotenone and rotenoids, *J. econ. Ent.*, **34,** 684

[2] White, D. G., Pagan, C. and Jones, M. A. (1948). Production of *Derris elliptica* in relation to type of cutting and age at harvest, *J. agric. Res.*, **77,** 13

[3] Moore, R. H. (1940). Investigations of insecticidal plants, *Rep. P.R. agric. Exp. Sta. 1939*, 71

[4] *Official and Tentative Methods of Analysis* (1950). 7th Edn. 70. Association of Official Agricultural Chemists

Book Reviews

SOIL ZOOLOGY

D. K. McE. Kevan (Ed.). Butterworths Scientific Publications: London, Academic Press: New York, 1955. xiv + 512 *pp.* (illus.) 55*s*, $10

Many people must have been influenced in their childhood by the game of clumps, of which I understand there is a modern radio version known as Twenty Questions. The first question was always ' Animal, Vegetable or Mineral ? ' and one naturally got the impression that these three ' kingdoms ' were mutually exclusive. Yet everyone knows that plants are dependent on the soil, and animals, either directly or indirectly, on plants; agriculturalists, at least, also know that the soil depends on plants for humus. But how many, even among soil scientists, realize the extent to which the structure of the soil and the formation of humus is influenced by animals, from Protozoa to rodents ? As Professor Hallsworth writes in the foreword ' One almost gains the impression, however, that to the professional soil worker, the occurrence of animals in the soil is an unfortunate accident, and one that should be ignored wherever possible, which generally seems to be whenever they or their activities are insufficiently obvious to be seen at once ! '

This book consists of fifty papers, together with discussions on them, by nearly as many authors. They were read at the Second Easter School in Agricultural Science, organized by the Nottingham University School of Agriculture in 1955. Part I contains six introductory papers, two on pedology, eight on ecology, seven on applied aspects and two on zoophagous fungi. It may seem disappointing that the pedological section (one article on animal activity in soils as a decisive factor in establishment of humus forms, and one on earthworms and soil structure) should be so short, but several papers in other sections include pedological aspects of various subjects. Part II contains fourteen papers on methods of sampling and estimation of numbers, two on culture methods, six on preparation techniques and three short articles on apparatus useful in physiological studies.

There is also an appendix by the editor giving an analytical key to the orders and suborders of animals inhabiting soil and litter, including so far as possible their immature stages. The system of classification adopted is admittedly ' somewhat unorthodox ' and will at first sight appear unfamiliar to most zoologists, but this does not detract from the value of this ambitious and on the whole very successful attempt to provide soil workers with a means of identifying the animals that will—or should—come to their notice.

It is not to be expected that all the articles should be of equal merit but most of them reach a high standard. Although the book does not claim to be a complete treatise on pedozoology (to coin a new word for a much neglected science) it is the nearest approach to one that has yet appeared and it should have a wide appeal to all soil workers, not only to zoologists.

The index, if anything, errs on the side of over-fulness, though it is questionable whether a list of over fifty page numbers without any sub-headings, such as appears under the entry *Collembola*, is of much value. —T.W.K.

PROGRESS IN THE PHYSIOLOGY OF FARM ANIMALS: VOL. II

J. Hammond (Ed.). Butterworths Scientific Publications: London, 1955. 740 *pp.* (illus.) 45*s*

The second of these volumes does not maintain quite the high standard of the first volume, nevertheless it is a very useful reference book, one which should be purchased by all animal workers in the tropics whatever their specific interest may be. In this volume various aspects of growth, animal behaviour, locomotion and reproduction are discussed. The first chapter deals with increases in body weight and Dr Pomeroy adequately discusses the various factors affecting live-weight growth. Dr Pálsson discusses in great detail changes in body form and composition; much of the classic lifetime studies of the editor and his associates have been included in these first two chapters.

It is unfortunate that the excellent review of wool growth by Dr H. R. Marston should have no bibliography, a particular necessity in a reference work. It was omitted, it is stated, because of the shortage of space; the editor's decision is to be regretted since there is some duplication in the first two chapters, which could have been more succinctly presented by telescoping them into one chapter, thereby leaving space for a bibliography on wool growth. Although it is realised that wool is not a tropical animal product of any great importance, the review by Dr Marston will provide useful background information to those working with other animal integuments, either in connection with skin physiology, or hide and skin production.

Whilst the reviews of grazing and sexual behaviour could have been more comprehensive, Dr Ottaway has produced an interesting chapter on various aspects on the mechanism of movement in farm animals. The final chapter in this volume has been written by Dr Fraps of the Agricultural Research Centre at Beltsville. Dr Fraps is well qualified to review egg production and fertility in poultry since he has been associated with this subject for many years, and much of the recent work in this field has emanated from the U.S.D.A. research service.—J.R.H.

LAND, WATER AND FOOD

H. Addison. Chapman & Hall, London, 1955. 248 *pp.* (illus.) 18*s*

Written by a specialist for the layman, this book deals with the fundamental problem of water in its relation to land irrigation and land reclamation problems and projects. After two preliminary chapters on climatic factors, the natural features of rivers and water control, the subsequent chapters survey on a global basis the great irrigation and water control works of the world, from Great Britain and Central Europe, through Africa and the east to Australia and the United States. The book, which is written in a simple, easy, conversational style, makes pleasant and informative reading and,

while it deals more particularly with problems of irrigation, the associated aspects of development, food supplies and the economic benefits resulting from these great achievements are not forgotten.—A.B.K.

PRINCIPLES AND PRACTICE OF FIELD EXPERIMENTATION

J. Wishart and H. G. Sanders. Commonwealth Bureau of Plant Breeding and Genetics: Cambridge, 1955. 133 *pp.* 21*s*

There is no doubt that a 'simple' book on field experimentation is required for the general agricultural student and perhaps also for some agricultural officers of over 20 years' service. In the last 20 years mathematical statisticians have proved themselves ingenious to the point of bewildering many of the old hands and frightening students with a plethora of experimental designs. Two distinguished authors have combined to produce such a book. It has the great merit of covering the whole field of the theory and practice of field experimentation. The statistical section covers all the important types of modern design without going into very voluminous calculations to explain them; the practical section gives an equally wide coverage of the problems that face the experimenter out in the field.

The manual, judged as an introduction for the uninitiated, does however raise some queries in the reviewer's mind. Was it necessary to keep the theory, the first part of the work, so severely separate from the more practical considerations ? If so, why not put the more palatable practice before the less digestible theory ? Is there much advantage in explaining principles largely by actual experiments ? The reviewer has often found that hypothetical figures can give a more convincing demonstration to the student. For example, confounding can be most clearly explained by means of a 2×2 experiment with blocks of two plots each, a design that would rarely be used in practice.

These criticisms, if they can be termed such, will, however, prove unfounded if the book becomes popular with the student as an introduction of what is to many a difficult subject. Such a manual is certainly needed. —A.L.J.

AGRICULTURE IN HAITI

M. A. Holly. Vantage Press: New York, 1955. 313 *pp.* (illus.) $3.50

The author sets out to describe agricultural conditions in Haiti and with this in view writes about the natural conditions of soil, climate and topography, about the peasant farmers who make up the bulk of the farming population, and about agricultural education and agricultural credit. In two chapters he deals briefly with the main crops and with the livestock of the country. The agricultural problems outlined will be familiar to those acquainted with tropical peasant farming conditions where standards of living are low.

The original material is freely interspaced with statistical tables of exports, imports, *etc*, and with extensive quotations from standard agricultural works, the implication being that the application of the principles enunciated in the extracts, to conditions in Haiti, is the solution to the agrarian problem. It is not so simple as that.

To one reader, at least, the book is disappointing and on the crop and livestock side inadequate. As presented the material is more in the nature of a student thesis; it cannot be regarded as a constructive contribution to the solution of the agricultural problems of Haiti.—A.B.K.

THE GENUS NICOTIANA

T. H. Goodspeed. Chronica Botanica Company: Waltham, Wm. Dawson: London, 1954. xxii + 536 *pp.* (illus.) $12.50

Most plant taxonomy is based on characters that can be seen on dead plant fragments with the eye, unaided or aided only by a hand lens. Quite frequently, such examination takes place thousands of miles away from the scene of collection and in these circumstances it is not surprising that taxonomy sometimes degenerates into what has been aptly but unkindly called ' the exhilarating sport of name-changing ', specimens being mounted, shuffled and matched like so many postage stamps. This kind of taxonomy is fortunately rare, for the results are dreadful. But even the best museum taxonomy is bound to be both incomplete and incorrect in some particulars, for the very nature of its materials forbids accuracy.

The function of taxonomy is not simply to name plants (that can be done on a postage stamp basis); it is to arrange them in biologically significant groups and to provide names for those groups. Of its nature, museum taxonomy can provide only clues to biological significance. Field work provides more information and experiment more still. The ideal is a taxonomy which draws on all sources of information, a taxonomy which is firmly founded on cytogenetic experiment but which also has command of all the relevant facts of geography, ecology and even anthropology, which obeys the International Rules of Nomenclature but regards biological sense as more important than rules and is on a scale large enough to avoid distortion of the emergent picture by biased sampling. The latter is important for there is a dangerous (though very natural) tendency to select pairs or small groups of species that illustrate in dramatic fashion one feature of evolutionary taxonomy at the expense of the larger picture; how many Ph.D.'s have been awarded for studies of meiotic misbehaviour in sterile F_1 hybrids between two nearly allied sympatric species ? And how many interfertile pairs have been passed over because it is impossible to write a thesis on meiotic normality ?

This ' ideal taxonomy ' demands much time, money, space, facilities for distant travel, an exceptionally wide grasp of diverse biological facts, and great persistence on the part of the investigator in filling in the duller details; and it rarely provides either spectacular economic results or a useful series of short-term research projects. It is therefore rare and in this reviewer's opinion there are probably fewer than a dozen genera or major subgeneric units which can be described as tolerably well understood. Even our crop plants are lamentably little known—the state of rice botany is one of the major disgraces of a civilization which calls itself ' scientific '.

This volume meeting, as it does, all the demands of the ' ideal taxonomy ' must place the group at or near the head of the list of ' understood genera '.

The volume is a large one; roughly two-thirds are devoted to Parts I to V (the distribution, morphology, cytology of species and hybrids, and phylesis) by Goodspeed alone, the remaining one-third to Part VI (taxonomy) by Goodspeed, H. M. Wheeler and P. C. Hutchinson. Part I is preceded by a very useful chapter entitled ' Objective and Argument ' which outlines the author's views on phylesis, as a background to the formidable mass of detail that follows. The viewpoint throughout is taxonomic, with a strong phyletic slant, and the economic botany of the group is explicitly excluded. Some 60 species are recognized, arranged in three subgenera: *Rustica* (three sections, nine species), *Tabacum* (two sections, six species) and *Petunioides* (nine sections, forty-five species); the first two subgenera constitute a Cestroid series (i.e. sections having *Cestrum*-like characters), the third a Petunoid series. The basic chromosome number of the group is probably six (as indicated, for example, by evidence from nucleoli) but polyploidy and secondary reductions have resulted in a complex series of numbers based on $n=9$, 10, *12* and 16, 18, 19, 20, 21, 22, *24*. Goodspeed's views on phylesis (admirably summarized in many diagrams) may be stated in his own words: ' . . . two alternating mechanisms, genetic differentiation and amphiploidy . . . to genetic differentiation . . . introgression has contributed '. The primary centre of origin was southern South America (where, for example, the functionally diploid parents, *N. sylvestris* and *N. otophora*, of the amphidiploid *N. tabacum* are found) but major secondary centres of diversity developed in western North America and in Australia. The facts of distribution, morphology and cytology that support these conclusions are fully set out in many tables and diagrams; the latter (with the possible exception of some cytological drawings photographically reproduced) are generally excellent. Part VI, the taxonomy of *Nicotiana*, is a formal treatment of the sixty species, complete with keys, specific descriptions, excellent line drawings by M. Blos of every species, lists of specimens determined and critical comments. The treatment is a model of what such treatments should be and now no botanist has any excuse for misidentifying a well-collected specimen of the genus. The book ends with 18 pages of references, two pages of index to authors and 21 pages of subject index. It is well made and excellently printed as, one feels, it should be for the price, but it seems a pity to disfigure three of the fly and title leaves with the publisher's advertisements.

In conclusion, this reviewer believes *The Genus Nicotiana* to be one of the greatest single achievements in plant taxonomy, a model of what taxonomy should be but so often is not, a monument to the energy and persistence of Professor Goodspeed and his collaborators, and an essential work of reference for the systematist and teacher.—N.W.S.

PLANT ECOLOGY: REVIEWS OF RESEARCH

UNESCO: Paris. 378 *pp.* \$7·00; £2 5*s*; 2,200 *fr.*

This comprehensive and authoritative publication describes in concise language the work that has been and is being done by member countries of UNESCO on the plant ecological problems relating to arid land reclamation and development. The subject is treated by experts each of whom knows

and understands the problem as it applies to his particular region. These regions consist of (*1*) Afghanistan, India and Pakistan, (*2*) Iran, Israel and Turkey, (*3*) Latin America, (*4*) Australia, (*5*) Irak, Jordan, Lebanon, Saudi-Arabia, Syria and Yemen, (*6*) Egypt, Eritrea, Libya and the Sudan, (*7*) Angola and South West Africa, Bechuanaland and the Union of South Africa, (*8*) North Western Africa, (*9*) the United States and Canada, and (*10*) tropical East Africa (Ethiopia, Somaliland, Kenya and Tanganyika). All these countries have an arid zone problem and this publication describes the plant ecological aspects of the work that is being carried out to solve this problem in each country. Each article is followed by a *resumé* in French and concludes with a fairly extensive bibliography.

The first point that is clearly brought out by these articles is the varying amount of attention that has been given to this vital subject of arid land development. UNESCO is doing great work in bringing to the notice of the various authorities the work that other countries are doing on problems similar to theirs. That this work of developing arid land is not equally advanced in each area is to be expected since resources are not the same nor is the problem equally urgent in each case, but the opening up of this research on a broad general basis will do much to stimulate the less fortunate countries in their attempts to deal with this problem.

The interchange of scientists between arid countries, each contributing knowledge as well as materials will do much to help; Dr Boyle of Australia has suggested that Australia might profitably exchange both men and information with Israel. Methods and information may be helpful but Dr Barucha has given the warning ' that there is a tendency . . . to try out exotic species just because they happen to be successful in regions with similar climatic conditions ' and he notes that ' it has been our common experience that the exotics are invariably swamped by the indigenous in competition '. The introduction of exotics cannot replace a sound ecological knowledge of a particular area and it is possible that the ' introduction ' may be of plants already present, but as yet unrecognized.

The cultivation and development of lands subject to arid conditions has been a problem studied since the earliest times and it is well recognized now that many deserts are man-made, but that man by suitably directed efforts can go far towards restoring the desert to productive land once again. Dyer notes that European settlement in South Africa has been attended by increasing desiccation of the country. ' So far the desert has the upper hand and little success has been achieved in stemming its advance '. This rather gloomy note is countered by Pilhawalla and Gorrie who studied the Rajputana desert and came to the conclusion that ' it is mainly man-made and with modern methods of engineering, preservation of moisture, controlled grazing, manuring and proper land management the desert can be reclaimed '. This more hopeful view can, I think, be applied to all those projects which are founded on a knowledge of the way of life of the inhabitants and their requirements coupled with a very definite knowledge of the ecological relations of the area.

These requirements for a successful project are again borne out in those man-made deserts which owe their creation to over-grazing, such as those occurring in Africa and America. The ecological effects of grazing cannot be

entirely separated from the effects of drought and other meteorological conditions and it has been pointed out by McGinnies that 'studies on the effect of grazing are also studies on the effects of climatic factors on the vegetation'; soil moisture is a limiting factor, and the rougher type of pasture is all that will survive on the low water contents of arid soils. Moderate grazing was shown to be less important than the climate in modifying the vegetation, but heavy grazing had an effect as great or greater than the effect of drought. While the climatic factors cannot be altered, much can be done to improve the pasture by an adequate study of its ecology. Sarvis has shown that native grasses deteriorate because of (*a*) too early grazing, (*b*) continuous grazing and (*c*) overgrazing; rotational grazing was superior to a continuous use. Recommendations founded on a knowledge of the relation of the type of grazing to the pasture structure can be formulated, but these recommendations, though excellent in a well-ordered society such as in Canada and U.S.A., are unpractical in arid areas where the sense of social responsibility among the inhabitants is not so well-developed. Measures recommended for restoring the denuded grassland may well conflict with social customs and usage and it is not surprising that they are not put into effect or meet with a passive resistance. The establishment of research stations working on well-planned and coordinated schemes should be coupled with an attempt to enlighten the inhabitants as to the why and wherefore of the different projects. The enforcement of such measures as appear wise and beneficial is a difficult task. The inhabitants will object to the imposition of measures contrary to or different from those practised in their forefathers' time, unless they can be taught that they and their flocks will benefit by their use. It often happened to the reviewer when laying out experiments designed to re-populate desert land with grass, that the ubiquitous goat devoured the young plants before they could grow and form a pasture. No amount of talking, threats or fines would convince the goat-owner that these experiments were designed other than as an immediate and pleasant windfall for his goats: the experiments had finally to be abandoned. It became more and more apparent that research findings were generally unsuited to pass on undiluted to persons of a lower educational standard who were accustomed to a different way of life. Education may be the only solution to the problem.

Much attention has been given to the study of the water relations of desert plants. Richter working in the Iran, Israel and Turkey region has divided the area into four ecological types, while attempts have been made to classify the morphology of these plants. Erenari's study of root systems has also added to our knowledge on this subject while Samueli has formulated a new method by means of which the water requirements of these plants can be easily and quickly determined. These discoveries though relatively small in themselves, in the aggregate make a sizeable contribution to the world's knowledge of its desert areas and their utilization.

The value of this review of plant ecological research as it applies to arid zone reclamation and development lies in its making available in concise language the results of past and present work and UNESCO is to be congratulated on yet another volume to assist it in its task of making two blades grow where one grew before.—F.W.A.

Recent Publications of The Imperial College of Tropical Agriculture

Studies in West Indian Soils, XII: The Agricultural and Forest Soils of St. Lucia, by F. HARDY and G. RODRIGUES. 5*s*

Studies in West Indian Soils, XIII: The Agricultural Soils of St. Kitts-Nevis with Notes on Statia (Dutch), by F. HARDY and G. RODRIGUES. 5*s*

A Report on Cacao Research, 1945–1951. 132 *pp.* fully illustrated in colour and black and white. 25*s*

A Report on Cacao Research, 1952. 8*s*

A Report on Cacao Research, 1953. 10*s* 6*d*

A Report on Cacao Research, 1954. 12*s* 6*d*

Reprints are available, at varying prices, of articles in the Cacao Research Reports, including the Colour-Illustrated Guide to the Diagnosis of Mineral Deficiencies in Cacao (1945–1951 Report)—Price 5*s* plus postage.

Memoirs—Economic Series No. 2: Peasant Farming: Report on Peasant Experimental Farms at the Imperial College of Tropical Agriculture, Trinidad, B.W.I., by A. L. JOLLY. 1*s*

Flora of Trinidad and Tobago: This Flora, which has been issued irregularly in parts since 1928, is a compilation of the work of many authors. The early parts, mainly by R. O. WILLIAMS, were edited by the Department of Agriculture of Trinidad and Tobago, but since the end of the second world war editing has been taken over by the Botany Department of the Imperial College. The Flora may be obtained either from the Department of Agriculture or from the Imperial College. The following parts have been published :

Volume I Ranunculaceae to Araliaceae complete in eight parts and index. 26*s* 6*d*

Volume II Part 1. Rubiales. 2*s*

Part 2. Asterales to Primulales. 3*s* 6*d*

Part 3. Ebenales to Polemoniales (in part). 5*s*

Part 4. Polemoniales (in part). 5*s*

Part 5. Scrophulariaceae to Acanthaceae. 5*s*

Part 6. Verbenaceae and Labiatae, 3*s* 1½*d*

Further parts are in preparation.

These and other publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad.

The *different* Scientific Monthly

RESEARCH

Science
and its
Application
in
Industry

Linking Scientific Research with Industrial Technique

Annual Subscription

60*s. sterling or* $10.00 *or* 3,000 *francs français, including postage*

From: **BUTTERWORTHS SCIENTIFIC PUBLICATIONS**

88 KINGSWAY, LONDON W.C.2

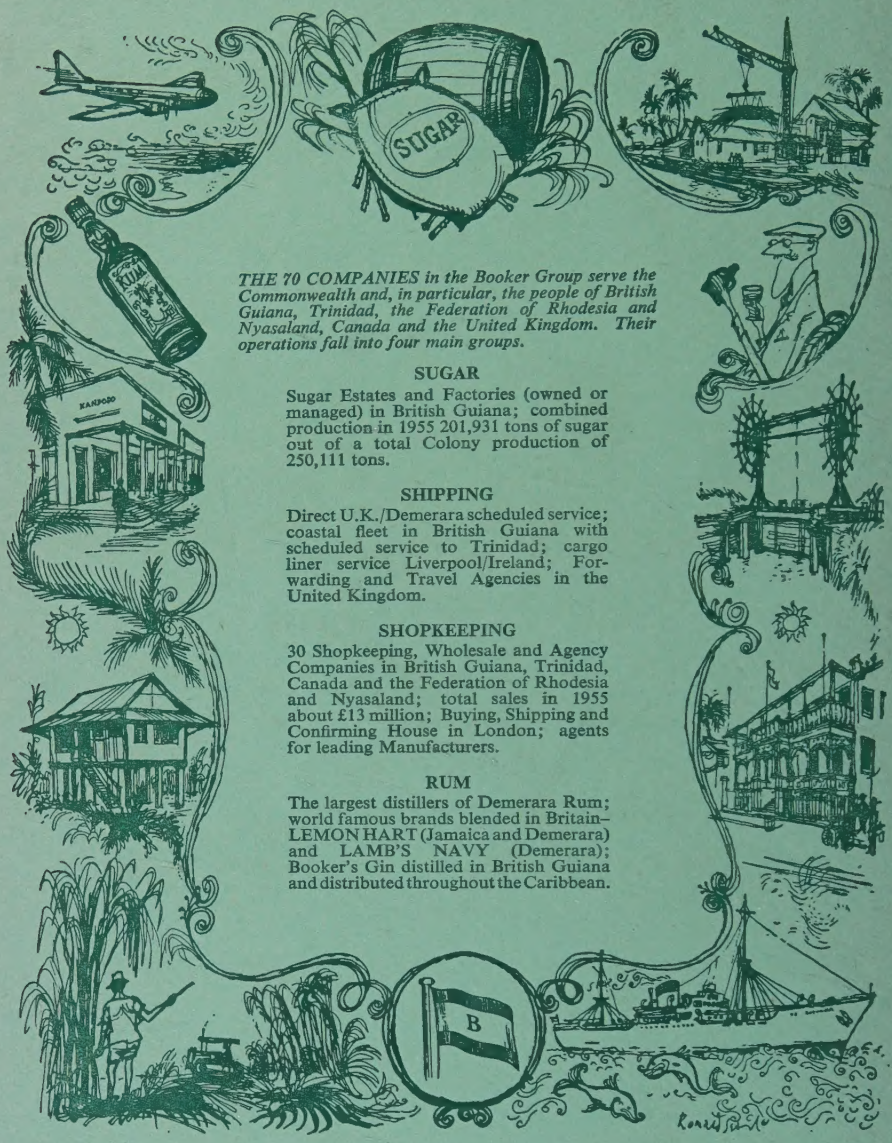
Interested in COFFEE . . .

The world over for very many years has relied on Bentall Machinery for processing coffee cherries. Most of the largest coffee factories are equipped with our machines, and thousands of small farmers use our hand-powered equipment. Our Technical Service Department is available to help you with your problems, so why not drop us a line and ask us for a catalogue or, when visiting England, you are cordially invited to visit our factory.

Bentall

★

E. H. BENTALL & CO. LTD · MALDON · ESSEX · ENGLAND



THE 70 COMPANIES in the Booker Group serve the Commonwealth and, in particular, the people of British Guiana, Trinidad, the Federation of Rhodesia and Nyasaland, Canada and the United Kingdom. Their operations fall into four main groups.

SUGAR

Sugar Estates and Factories (owned or managed) in British Guiana; combined production in 1955 201,931 tons of sugar out of a total Colony production of 250,111 tons.

SHIPPING

Direct U.K./Demerara scheduled service; coastal fleet in British Guiana with scheduled service to Trinidad; cargo liner service Liverpool/Ireland; Forwarding and Travel Agencies in the United Kingdom.

SHOPKEEPING

30 Shopkeeping, Wholesale and Agency Companies in British Guiana, Trinidad, Canada and the Federation of Rhodesia and Nyasaland; total sales in 1955 about £13 million; Buying, Shipping and Confirming House in London; agents for leading Manufacturers.

RUM

The largest distillers of Demerara Rum; world famous brands blended in Britain—LEMON HART (Jamaica and Demerara) and LAMB'S NAVY (Demerara); Booker's Gin distilled in British Guiana and distributed throughout the Caribbean.

BOOKER BROS., McCONNELL & Co LTD

37/41 GRACECHURCH STREET, LONDON, E.C.3

PUBLISHED QUARTERLY BY BUTTERWORTHS PUBLICATIONS LTD., 88 KINGSWAY, LONDON, W.C.2. PRINTED IN GREAT BRITAIN BY R. J. ACFORD LTD., CHICHESTER, SUSSEX. ANNUAL SUBSCRIPTION INCLUDING POSTAGE—IN U.K. £2.; IN U.S.A. $5.60. ALL RIGHTS RESERVED. DISTRIBUTORS ALL COUNTRIES EXCEPT U.K., U.S.A., CANADA, AUSTRALIA, NEW ZEALAND AND SOUTH AFRICA: I. R. MAXWELL & Co. LTD., 4-5 FITZROY SQUARE, LONDON N.W.1.